
Water Quality Issues and the Importance of Riparian Vegetative Buffers
Dr. William Reay, Director, Chesapeake Bay National Estuarine Research Reserve Virginia

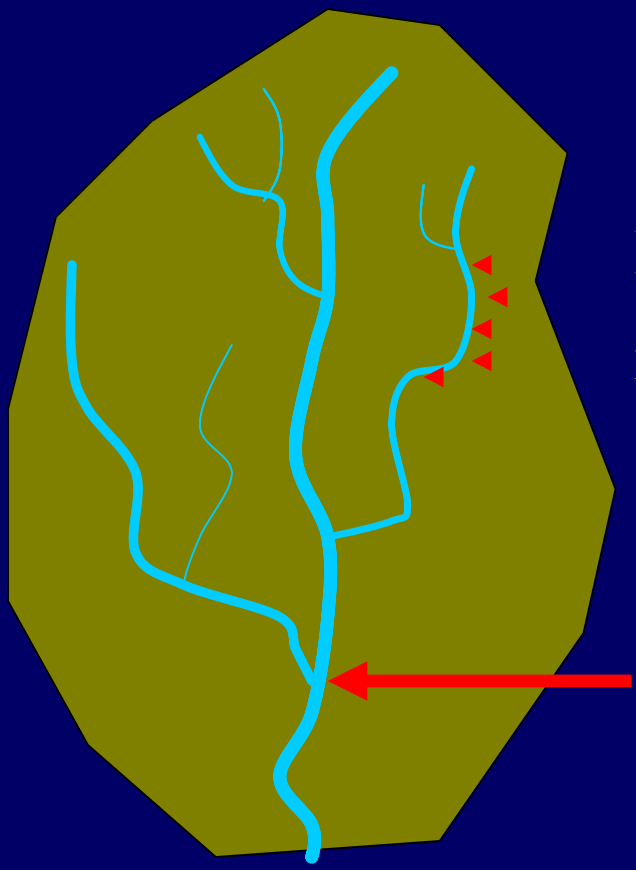
Presentation Overview

- Contaminants of Interest
- Water as a Transport Medium
- Riparian Buffers
- Water Quality Functions

Primary Vegetative Buffer Values

- **Water Quality Protection/Remediation**
  - surface water runoff
  - groundwater drainage
- **Erosion Control**
  - upland
  - in-stream
- **Wildlife Habitat Enhancement**
  - upland
  - in-stream
- **Economic Value**
  - lumber/pulp products
  - firewood
  - forage/hay
  - nuts/fruits

Nature of Contaminant Inputs



Watershed or Drainage Basin

Natural unit of land bounded by its drainage divide and subject to surface and subsurface drainage to a common outlet region.

Nonpoint Source

Origin of discharge is diffuse
Discharge may be transient in time

- **Runoff from cropland**
- **Effluent from septic systems**
- **Highway de-icing salts**

Point Source

Inputs with well defined point of discharge
Discharge is usually continuous

- **Leakage from landfills and storage tanks**
- **Wastewater treatment facilities**
- **Industrial inputs**

Common Classes of Pollutants

Rural Areas

- Thermal Stress
- Sediment
- Pathogens
- Nutrients
- Pesticides

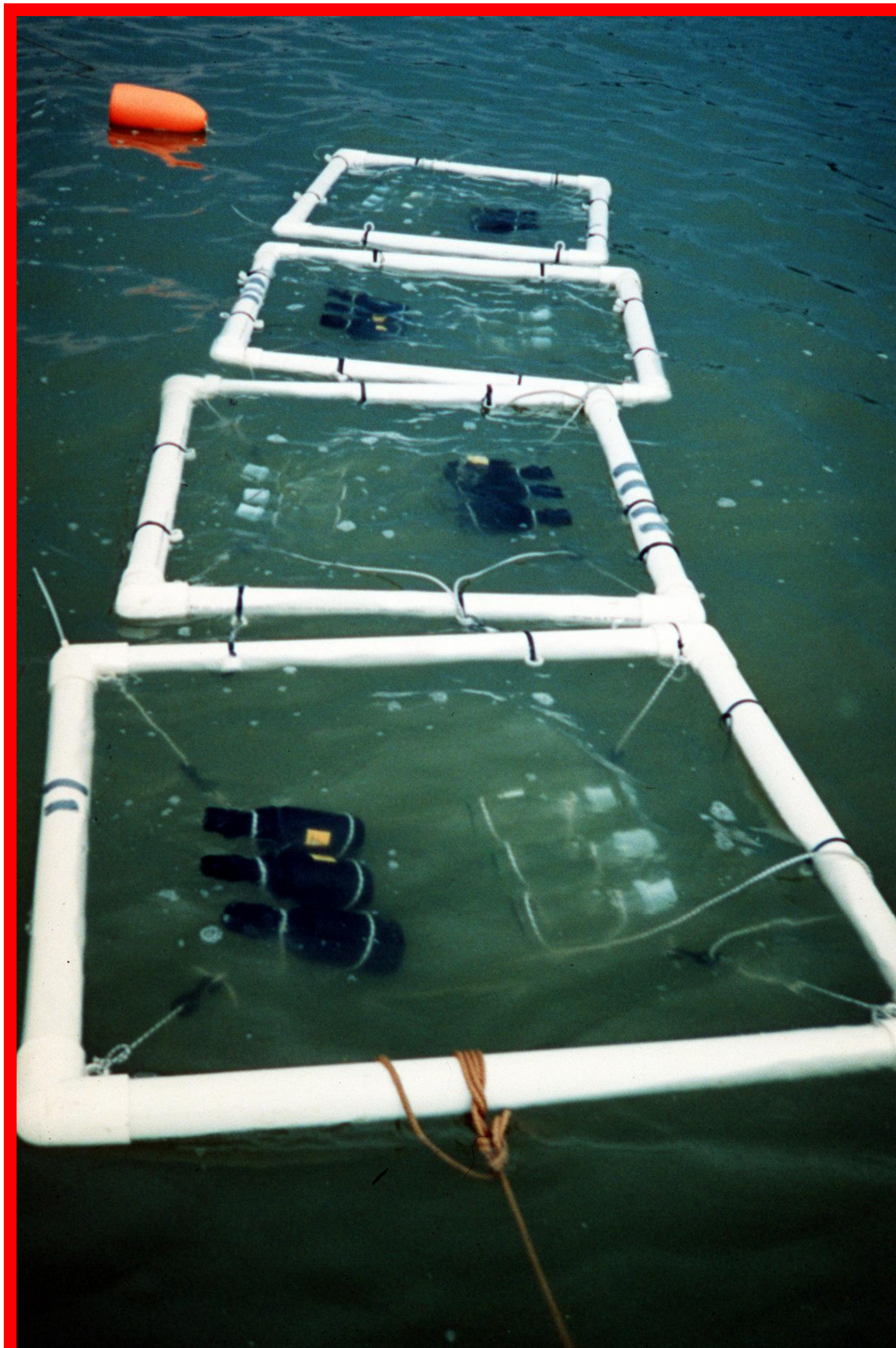
Urban Areas

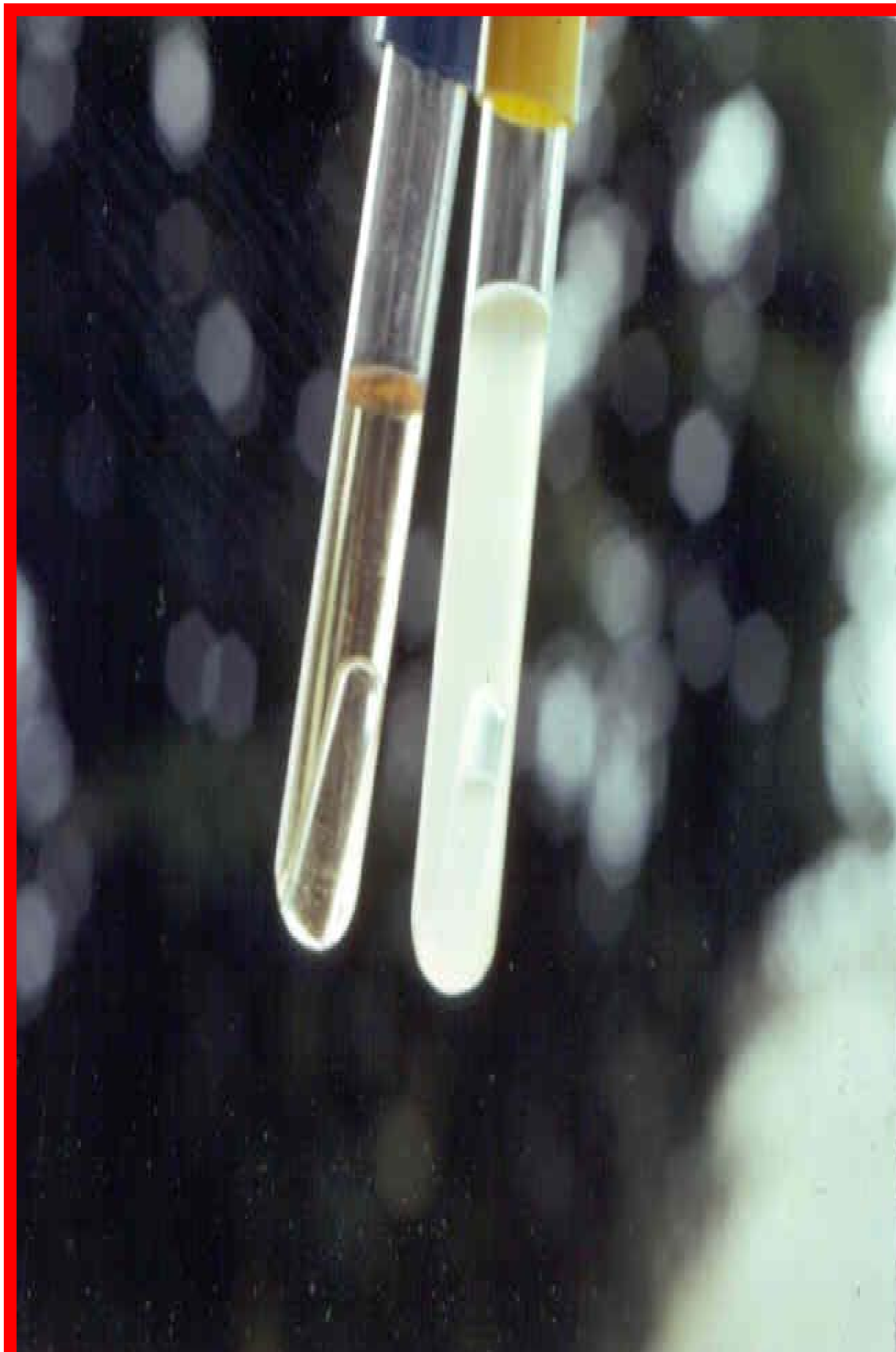
- Sediment
- Pathogens
- Nutrients
- Heavy Metals
- Petroleum Products
- Road Salt
- Thermal Stress

Temperature Regulation

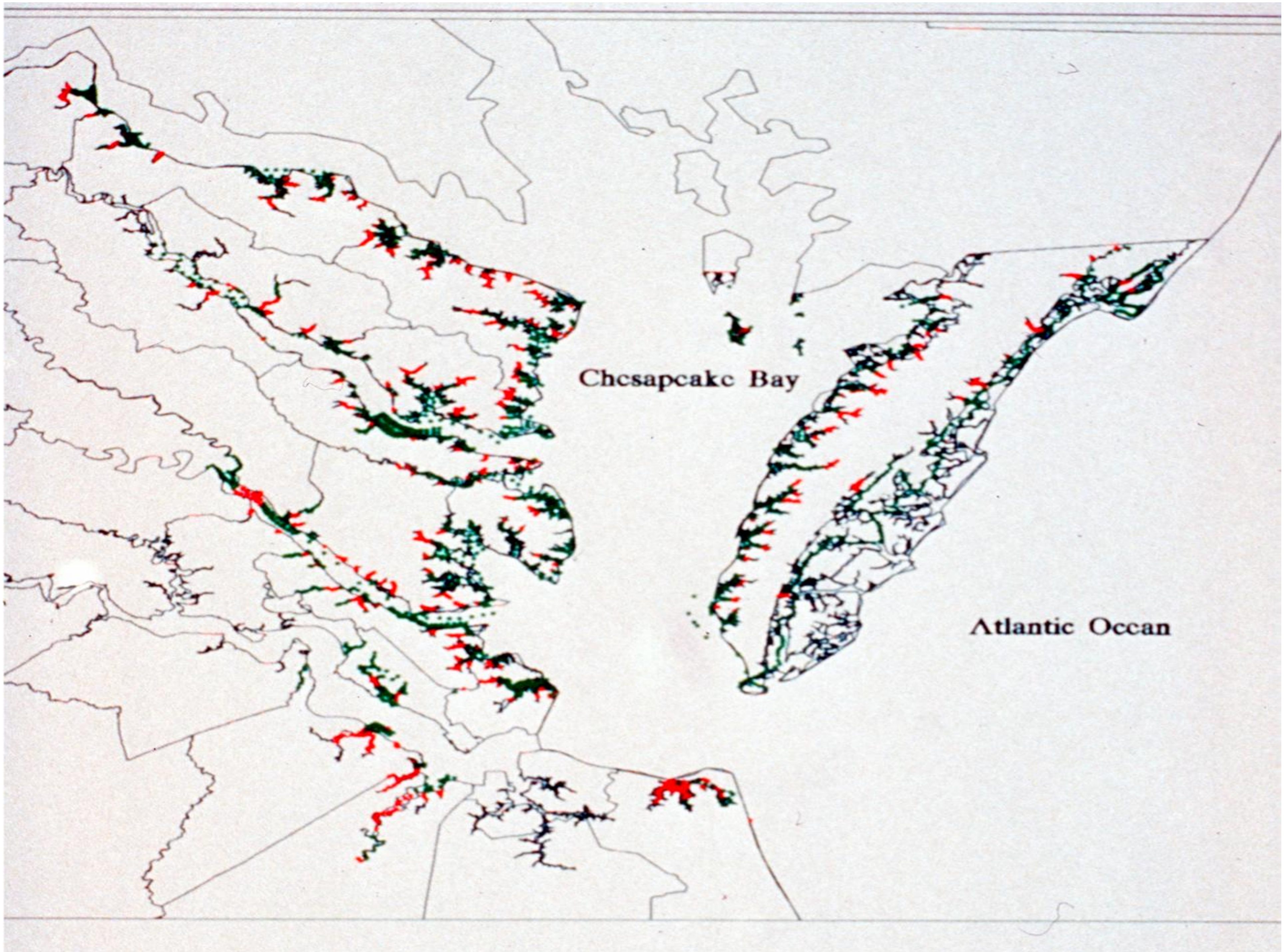
Sediment Loadings

Nutrient Enrichment



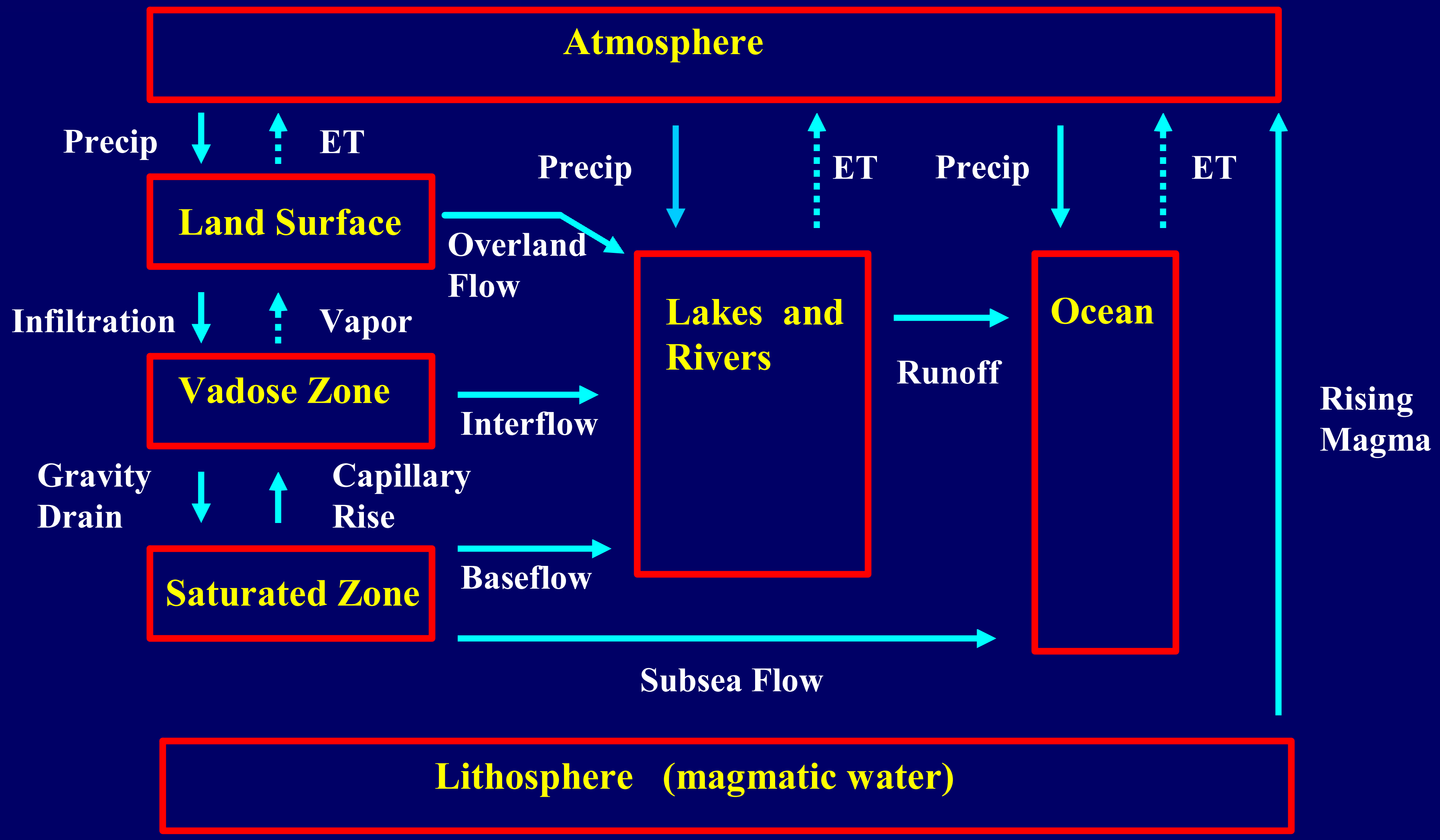


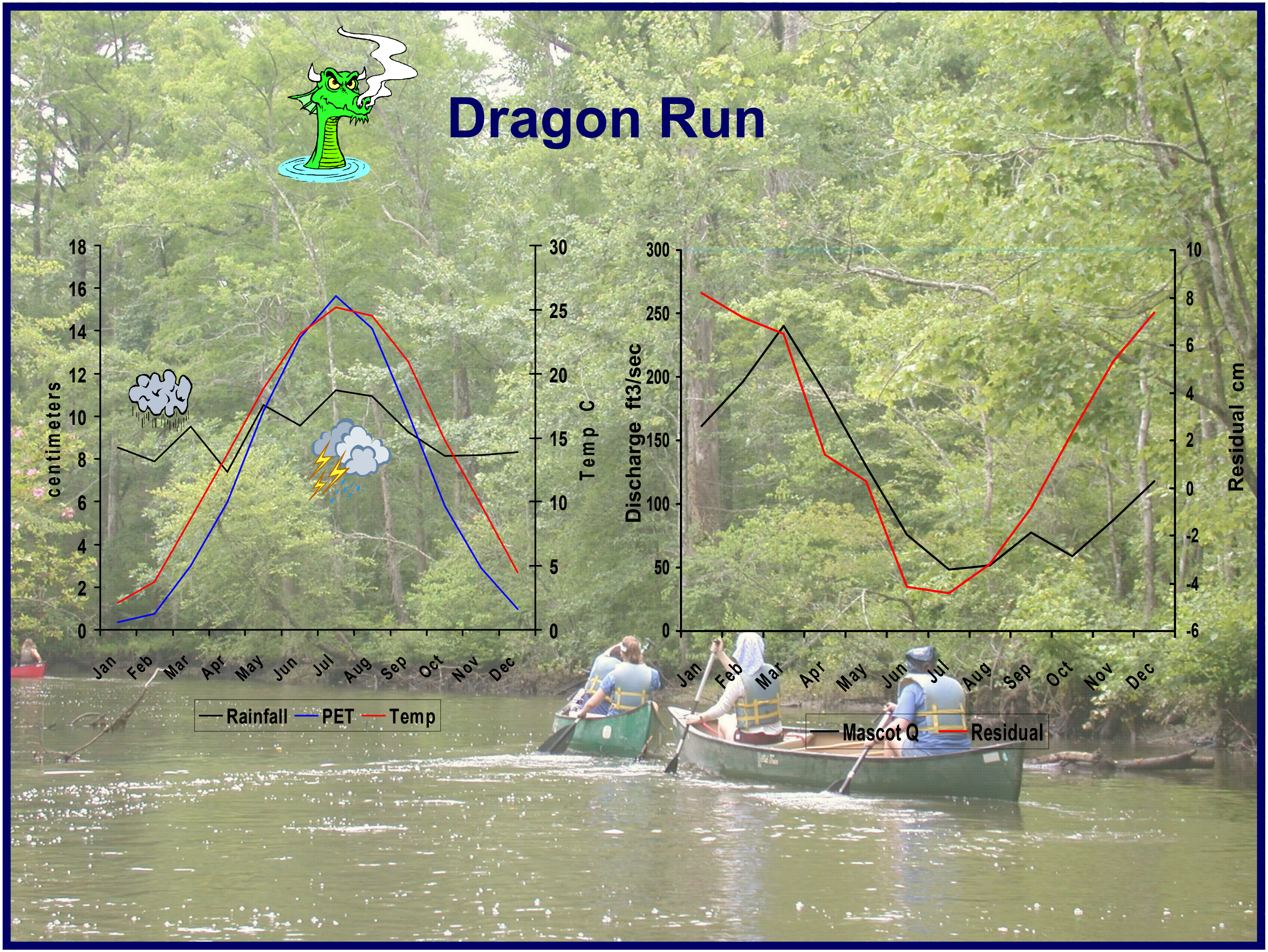
Microbial Contamination


Chesapeake Bay
Atlantic Ocean

Water
A Transport Medium

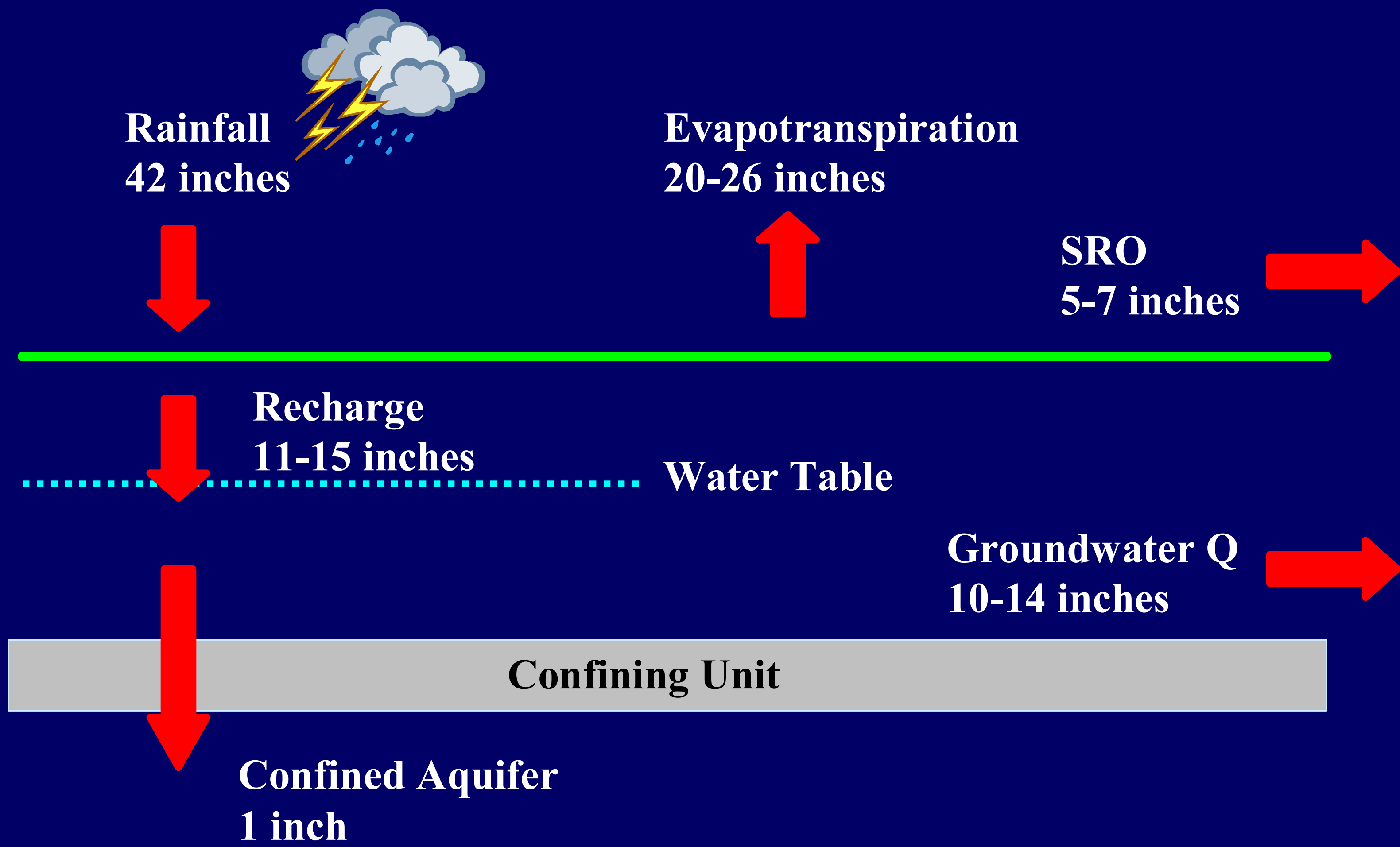
Hydrologic Cycle





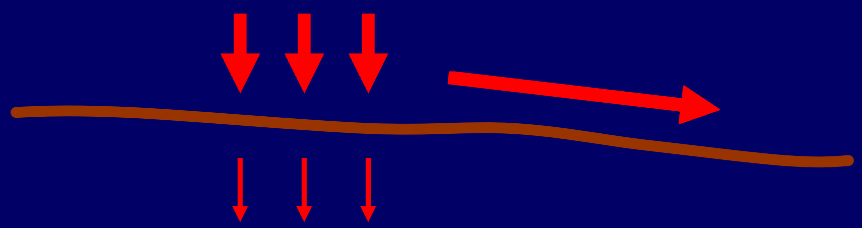
Dragon Run
centimeters
Temp C
Rainfall
PET
Temp
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Discharge ft3/sec
Residual cm
Mascot Q
Residual

Estimated Water Budget
Coastal Plain - VA

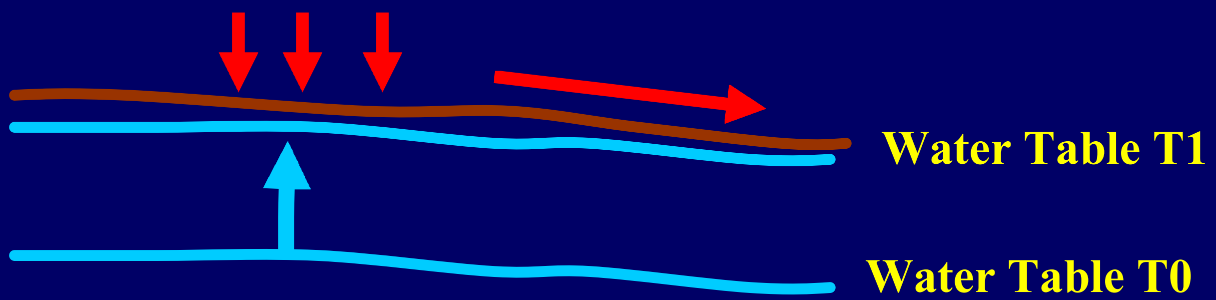


Surface Runoff Mechanisms

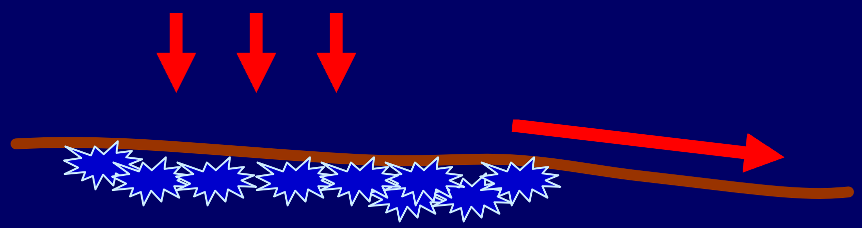
1. Hortonian Overland Flow



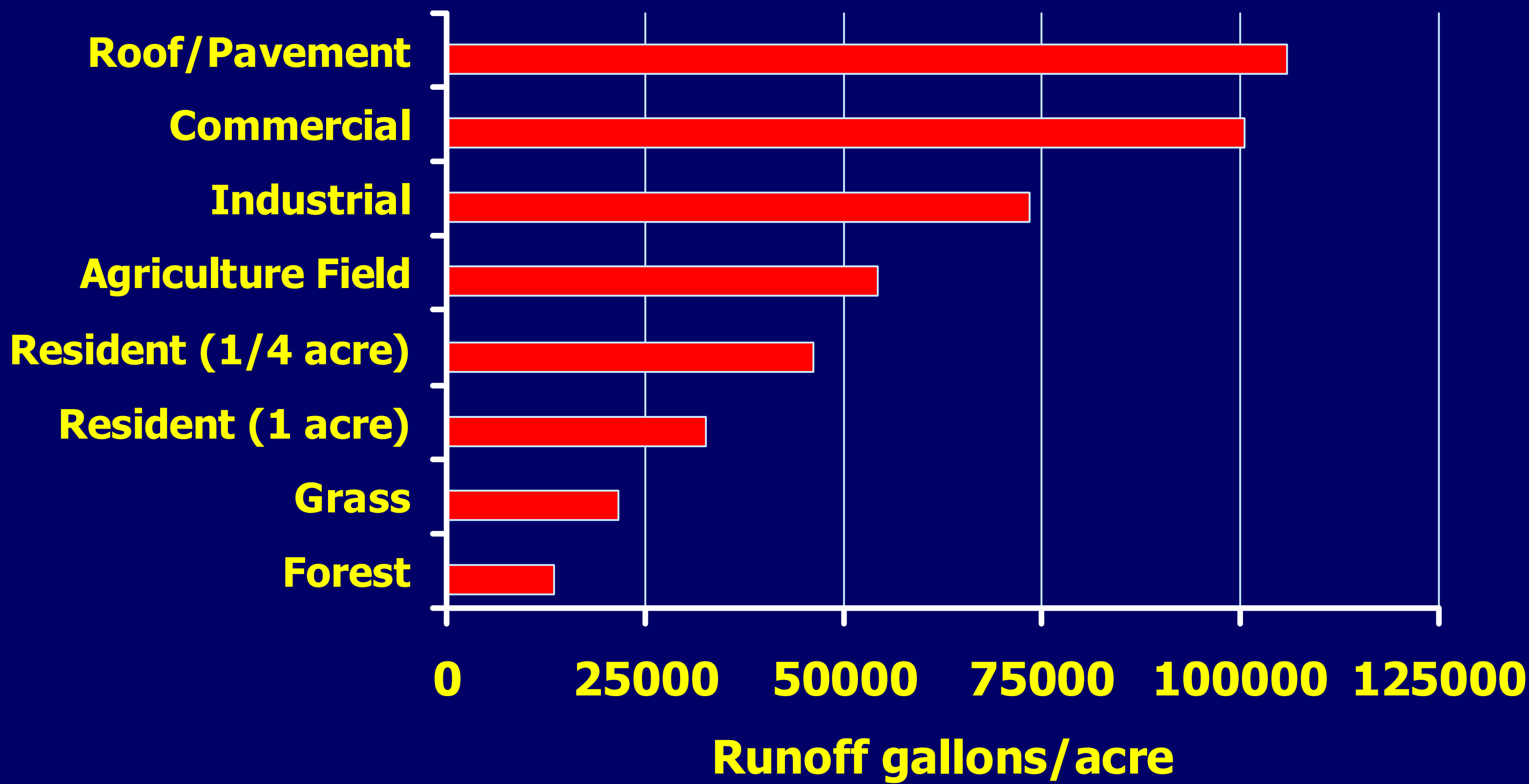
2. Saturation Overland Flow



3. Frozen Soil Conditions

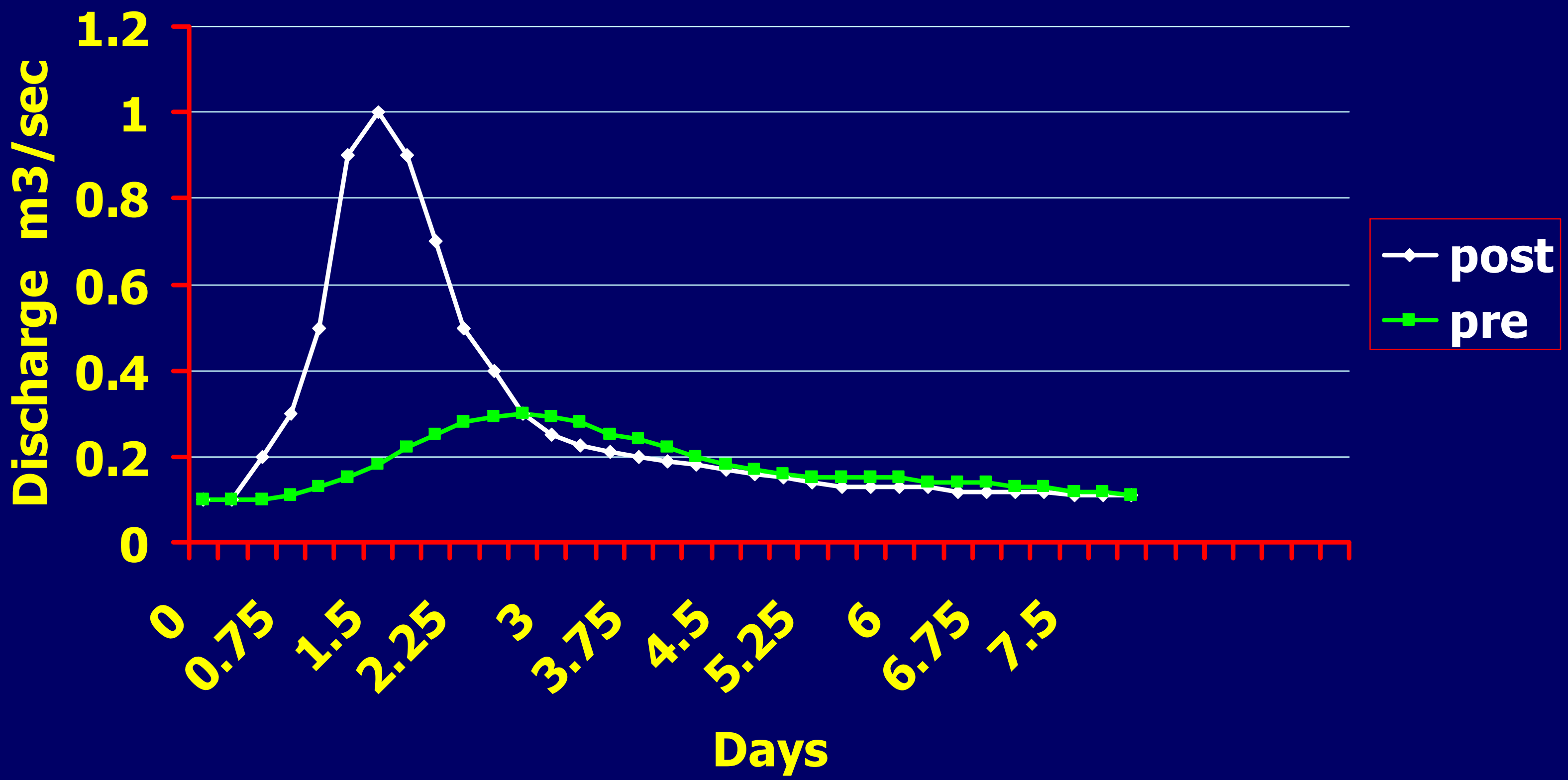


Estimated Runoff versus Land Use
4 inch Rain

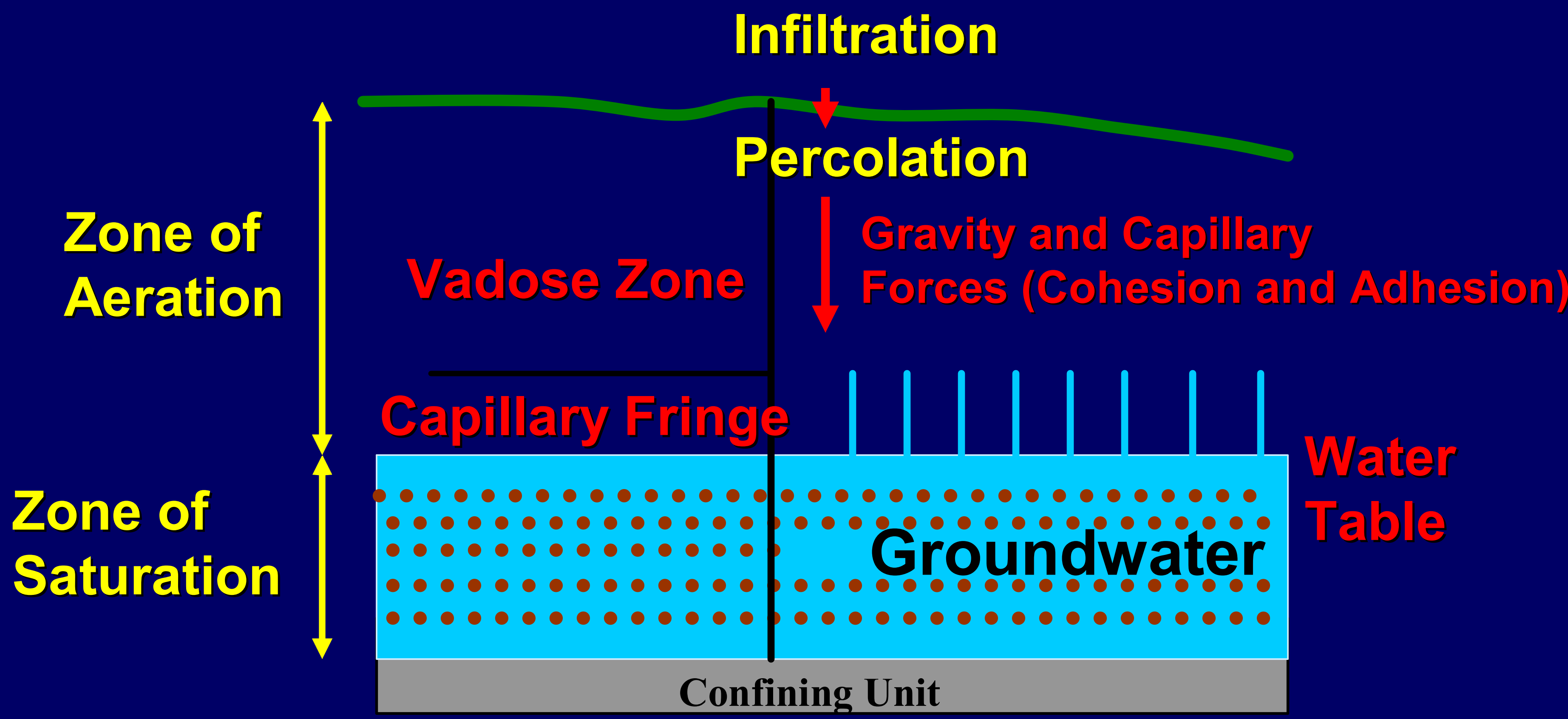


100% Ruoff = 108,000 gal.

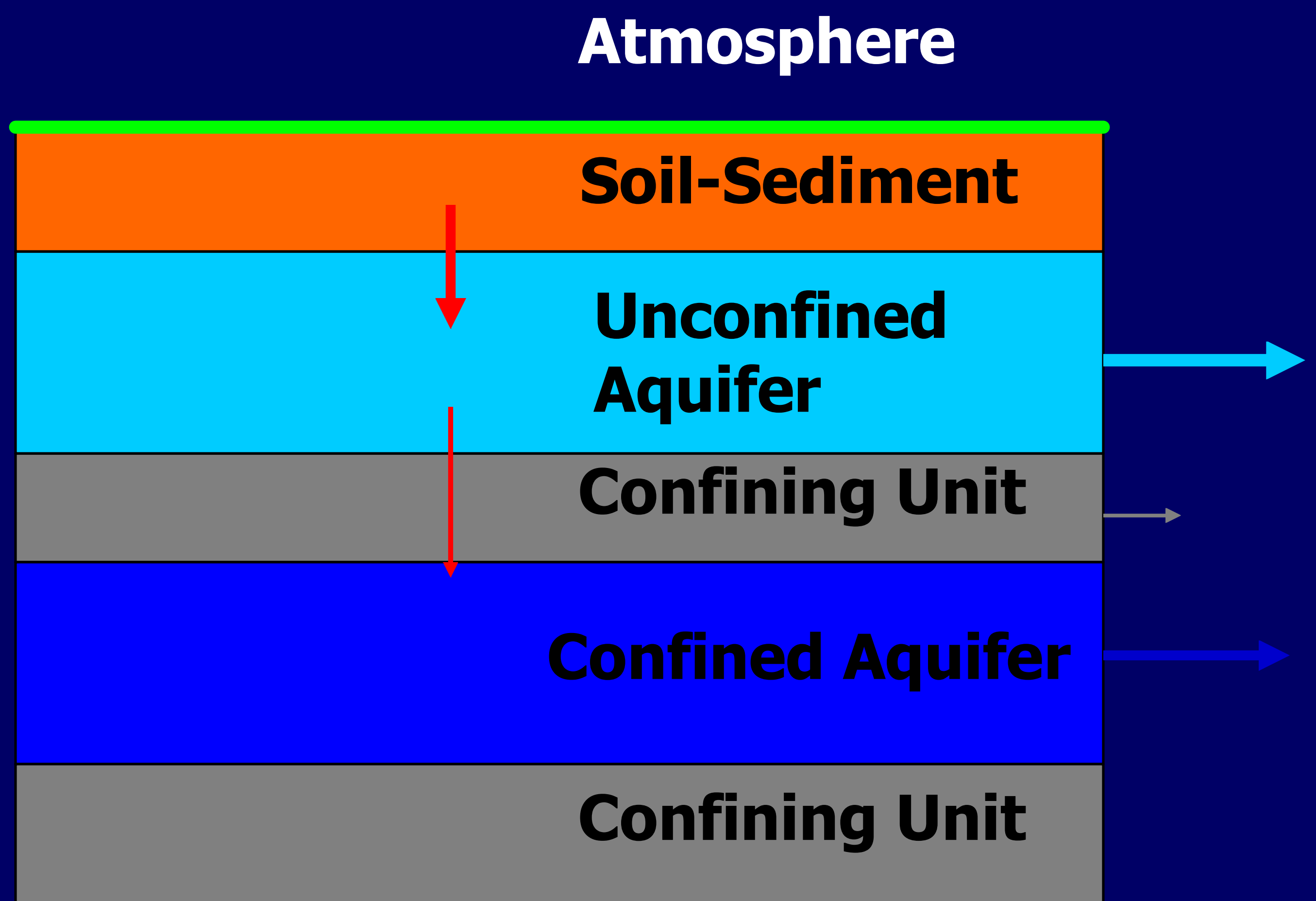
Effect of Development on Storm Runoff



Distribution of Subsurface Water

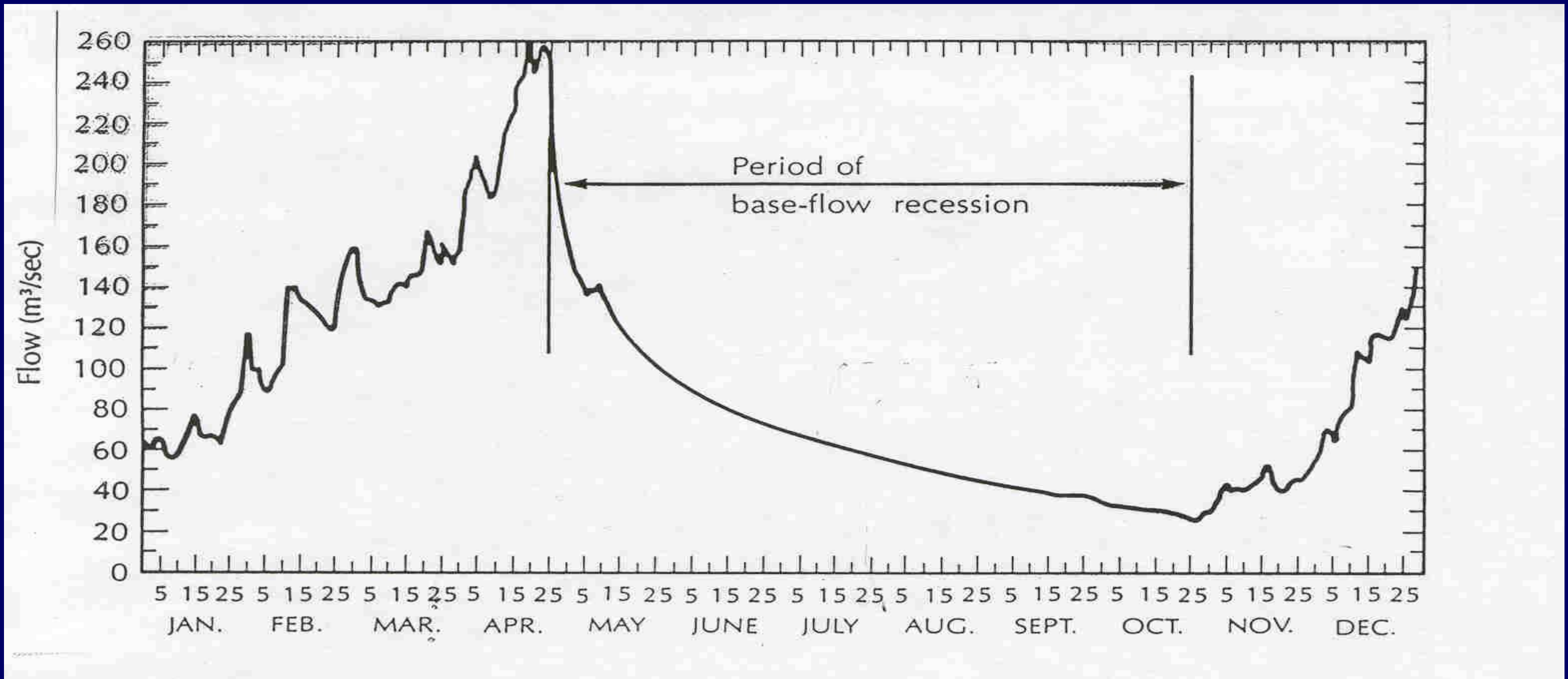


Aquifer Types

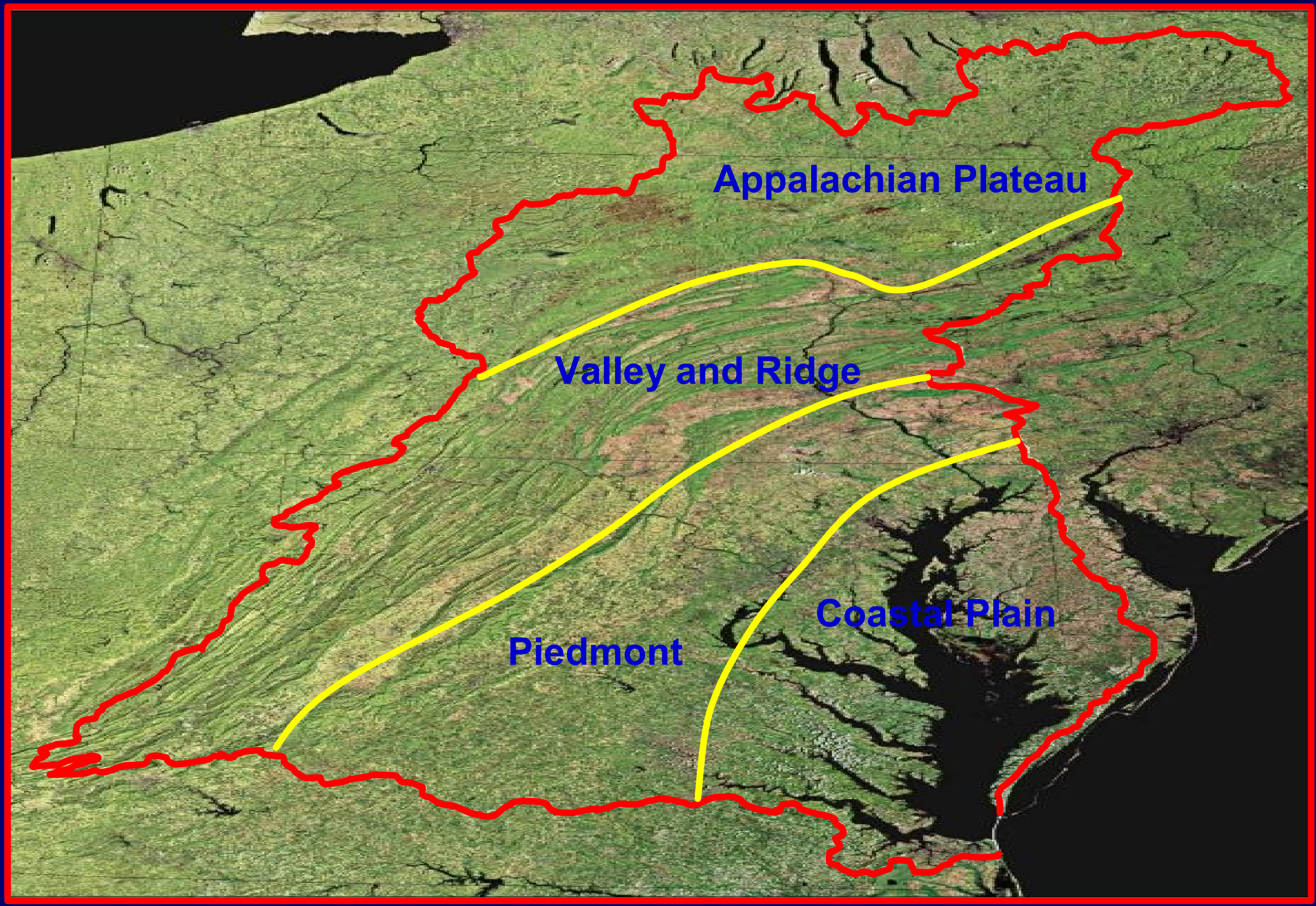


Baseflow

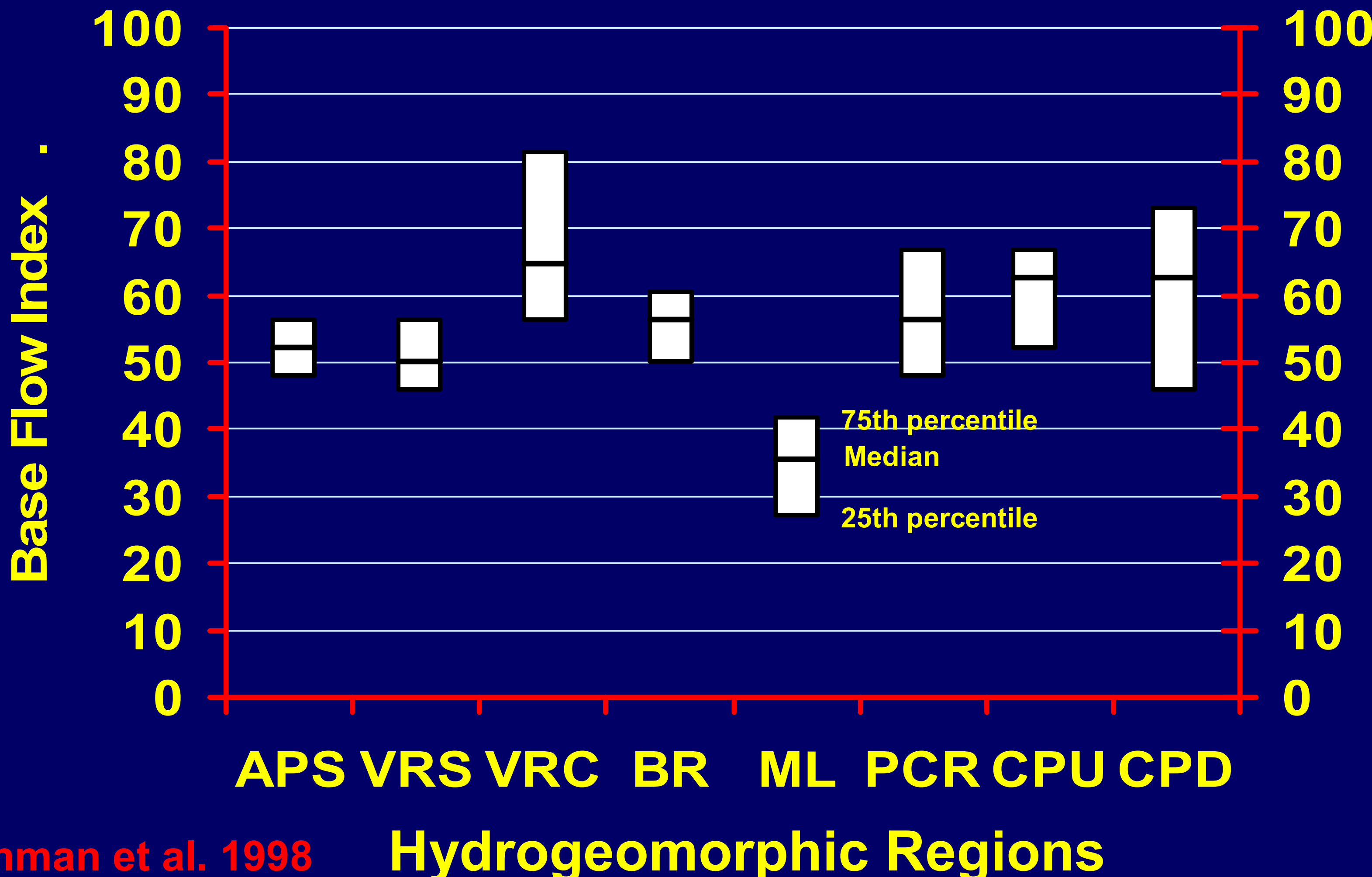
Ground Water discharged to nontidal streams and rivers



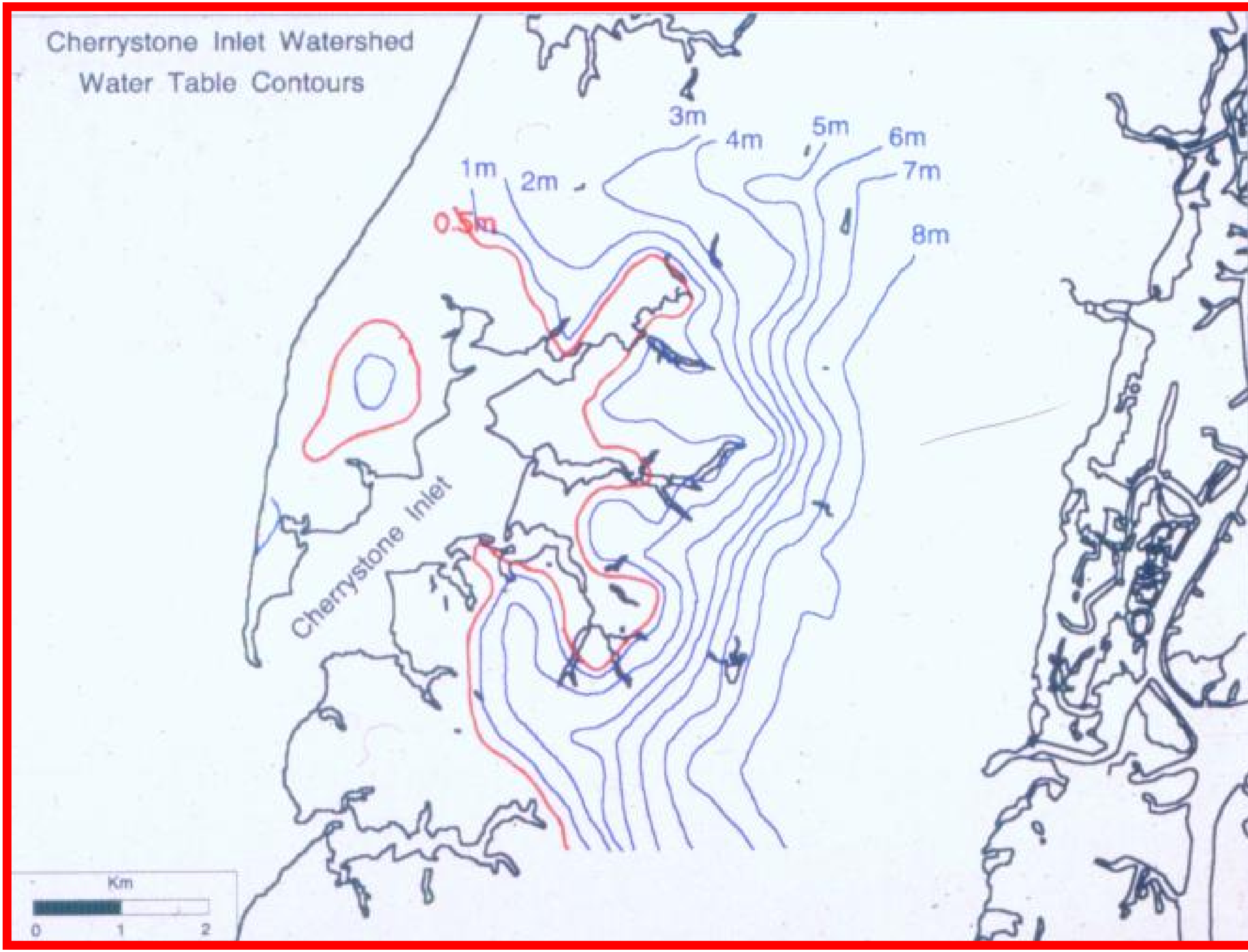
General Physiographic Regions of Chesapeake Bay Watershed



Base Flow Index
Chesapeake Bay Watershed

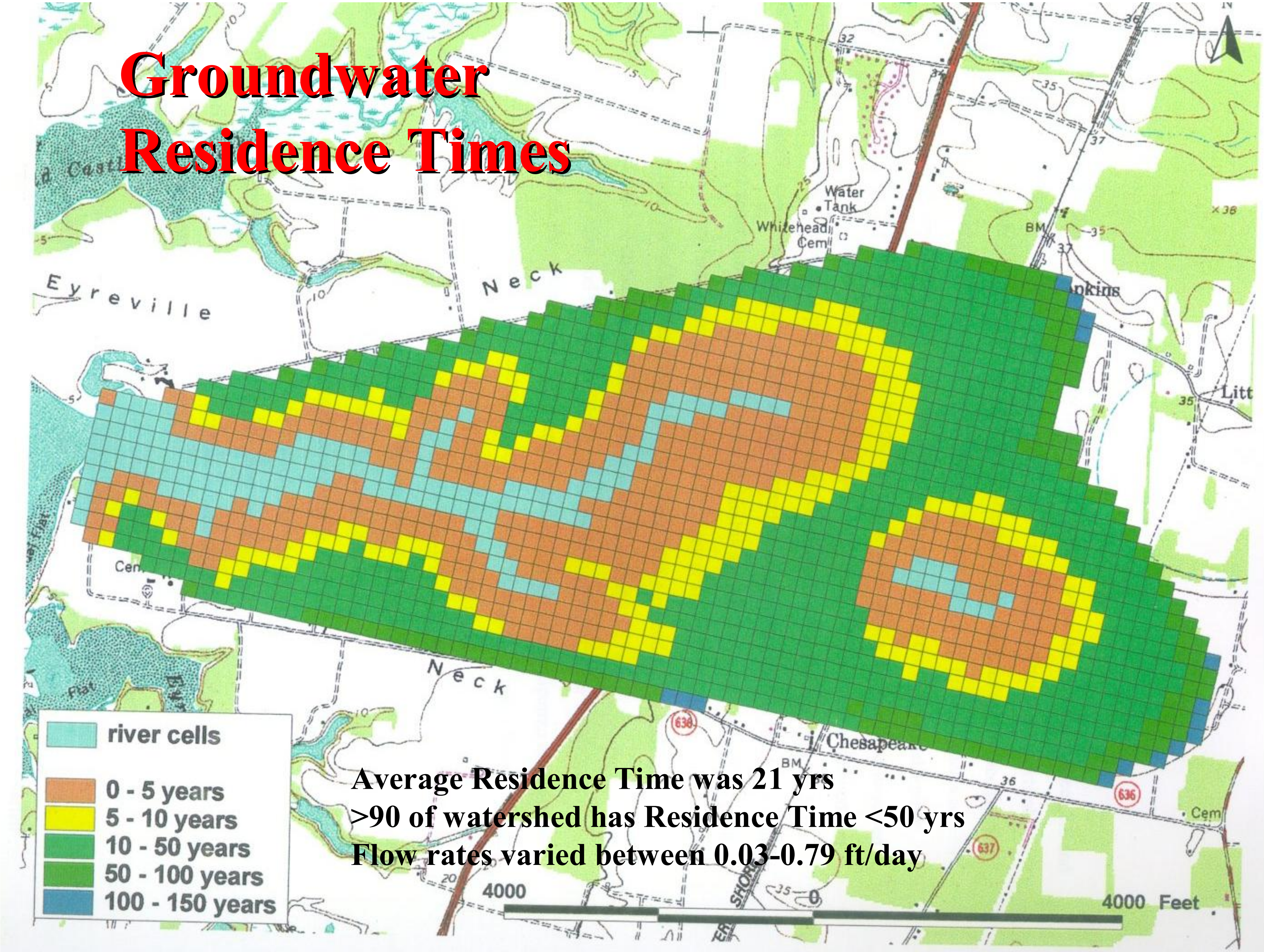


Bachman et al. 1998



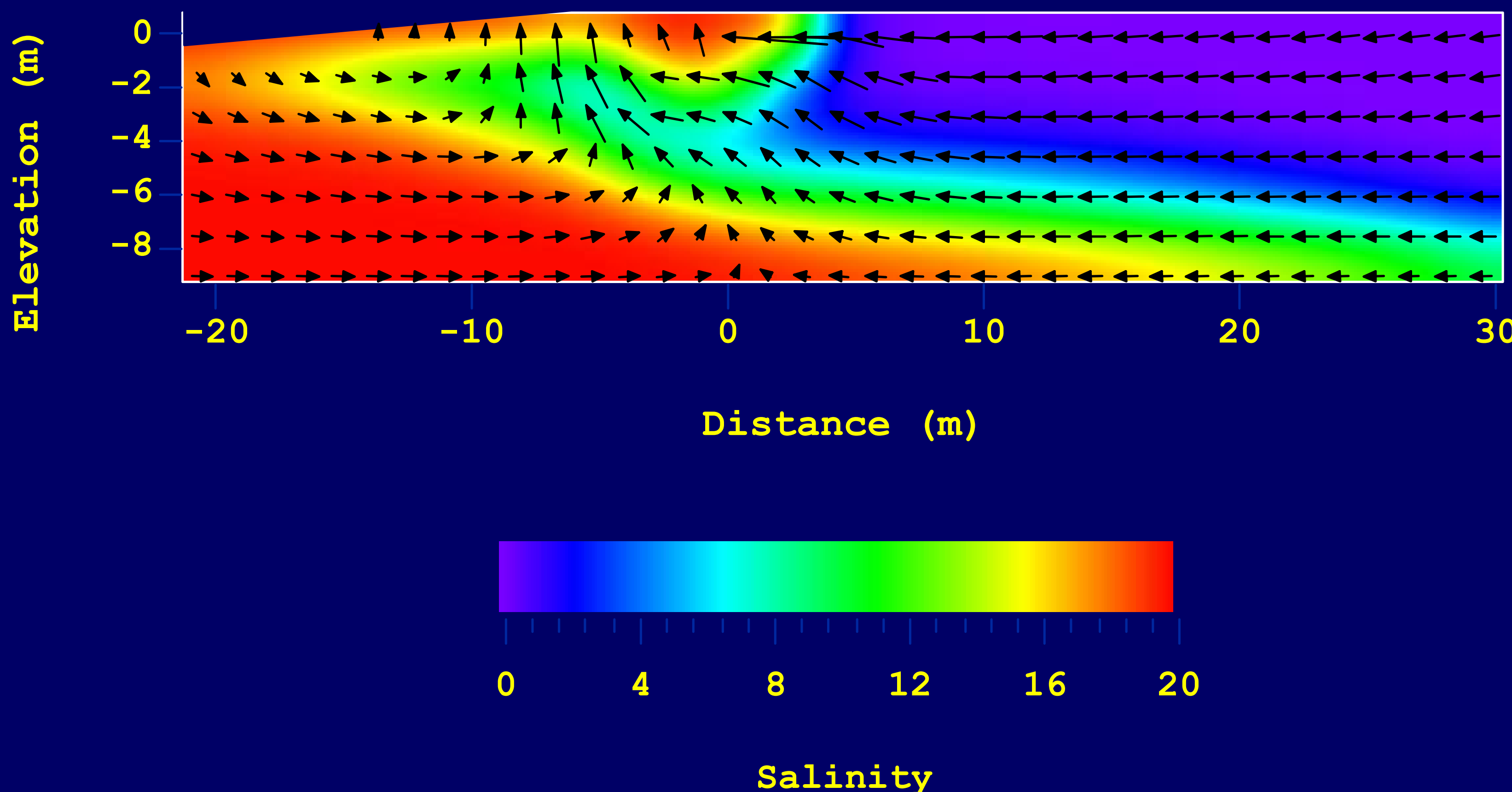
Cherrystone Inlet Watershed
Water Table Contours
0.5m
1m
2m
3m
4m
5m
6m
7m
8m
Cherrystone Inlet
Km
0
1
2

Groundwater Residence Times

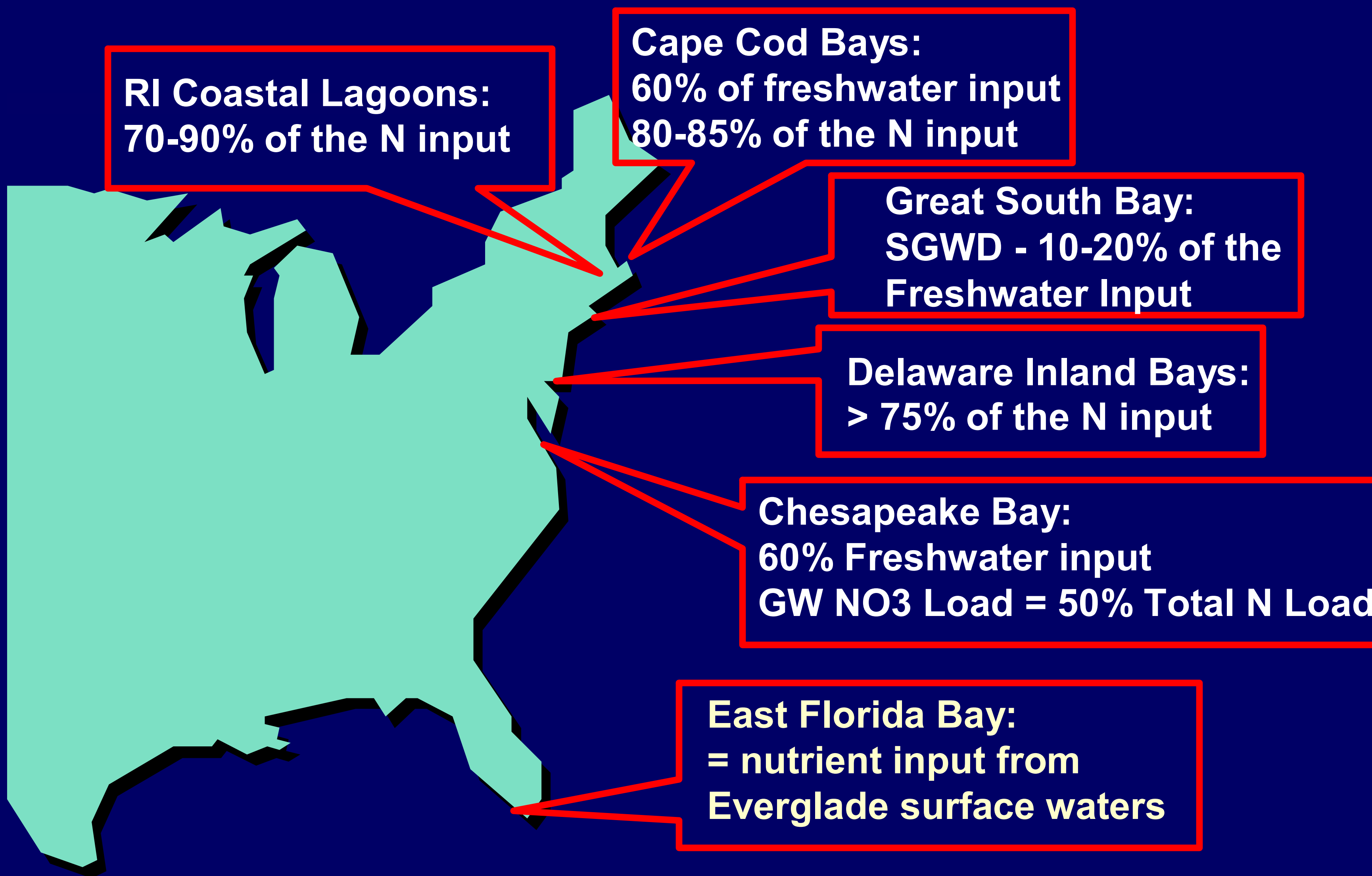


Average Residence Time was 21 yrs
>90 of watershed has Residence Time <50 yrs
Flow rates varied between 0.03-0.79 ft/day

Nearshore Mixing Patterns



Importance of Groundwater Discharge to Coastal Systems

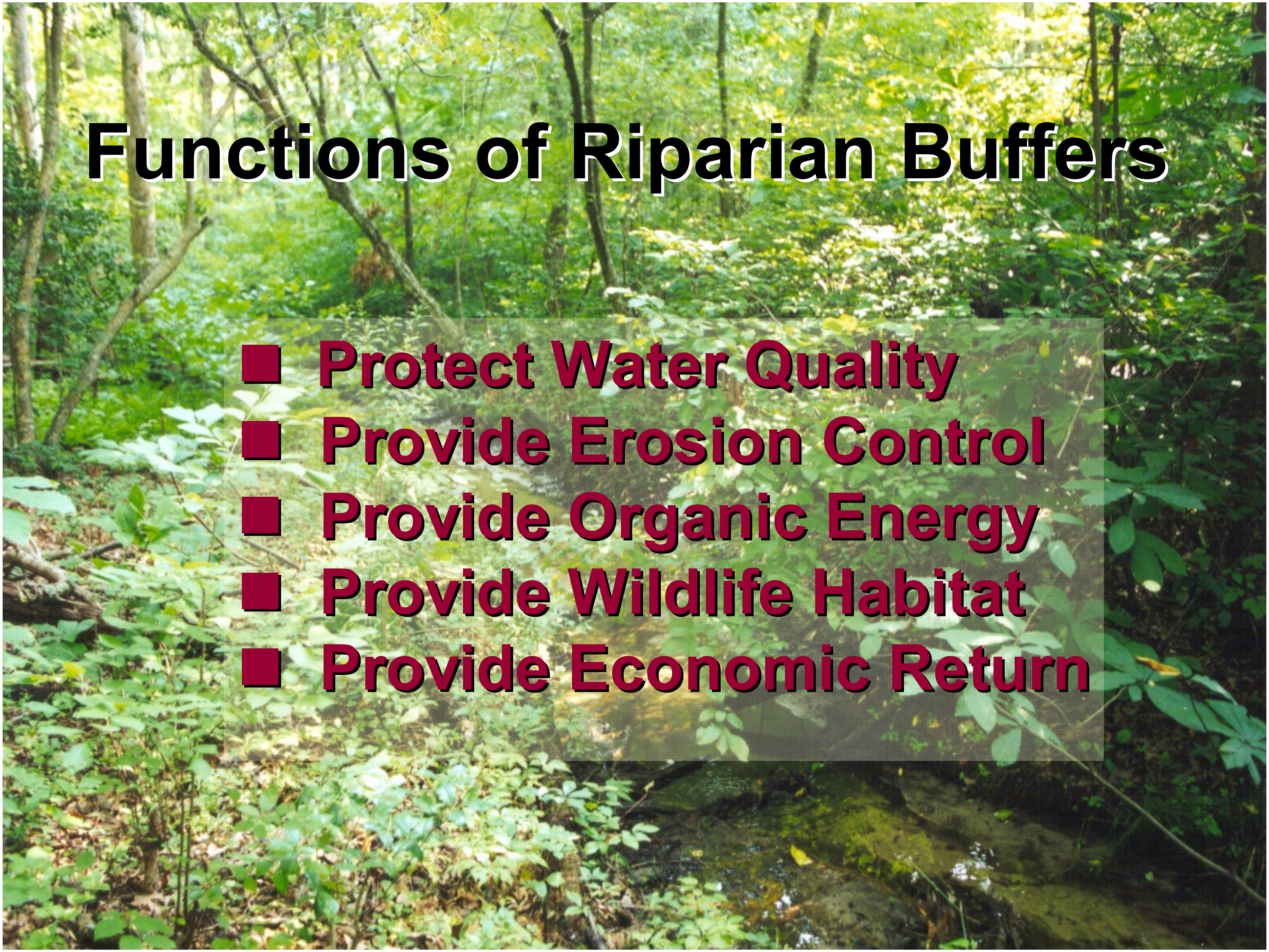


Factors Affecting Overland and Groundwater Flow

- **Climatic**
  - Storm type
  - Storm characteristics
  - Precipitation distribution
  - Precipitation type
- **Topographic**
  - Drainage basin size/shape
  - Elevation/orientation of Basin
  - Land and water course slopes
  - Distribution of water courses
  - Detention reservoirs

Factors Affecting Overland and Groundwater Flow

- **Geologic**
  - Top soil characteristics
  - Hydraulic conductivity of subsoil/sediment
  - Location of impervious formations
- **Vegetative**
  - Rainfall interception
  - Plant distribution in basin
  - Plant water demands
- **Human Alteration**
  - Water control structures
  - Water use
  - Changes in land use patterns and activities



Functions of Riparian Buffers

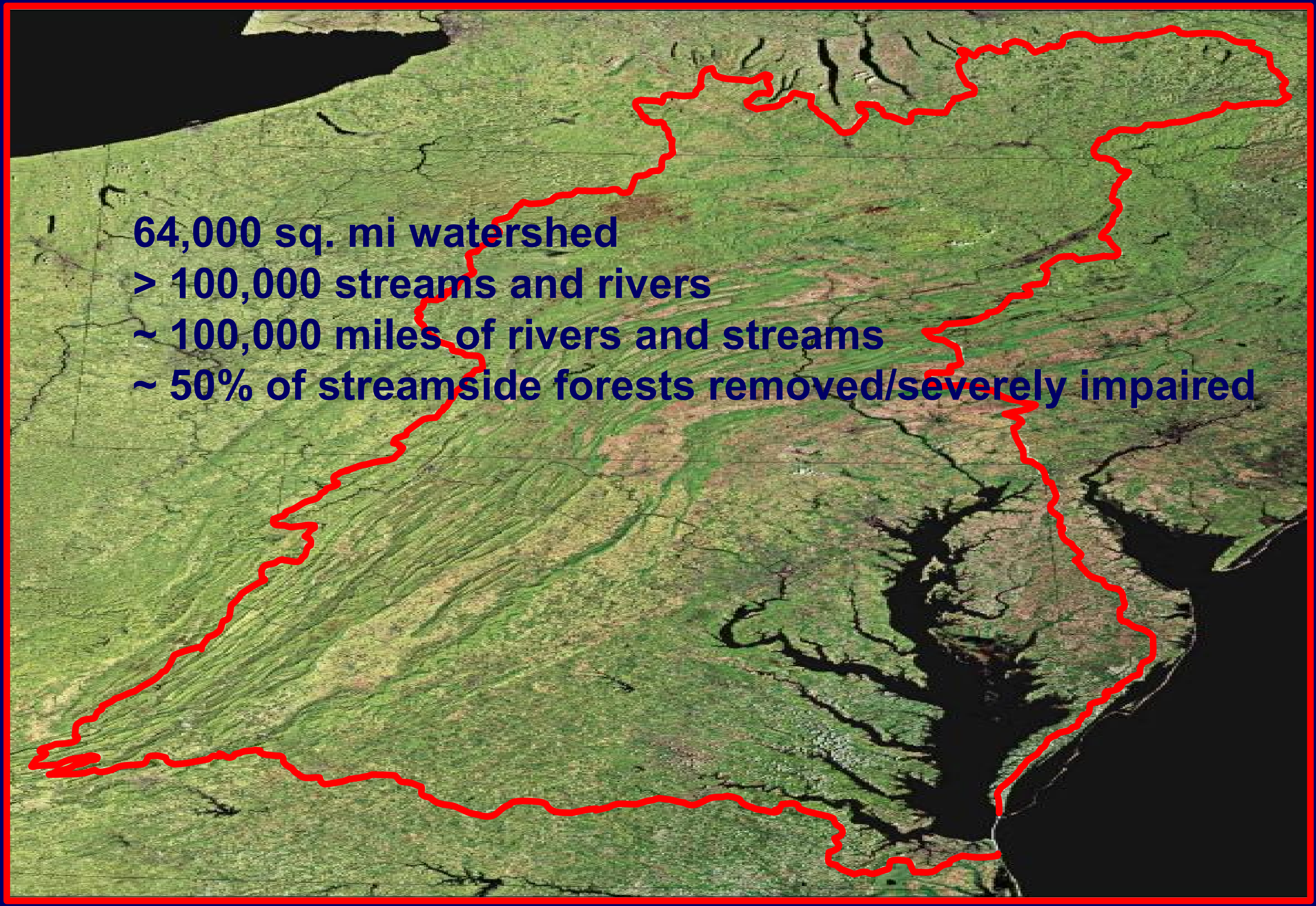
- Protect Water Quality
- Provide Erosion Control
- Provide Organic Energy
- Provide Wildlife Habitat
- Provide Economic Return

Riparian Buffer Defined

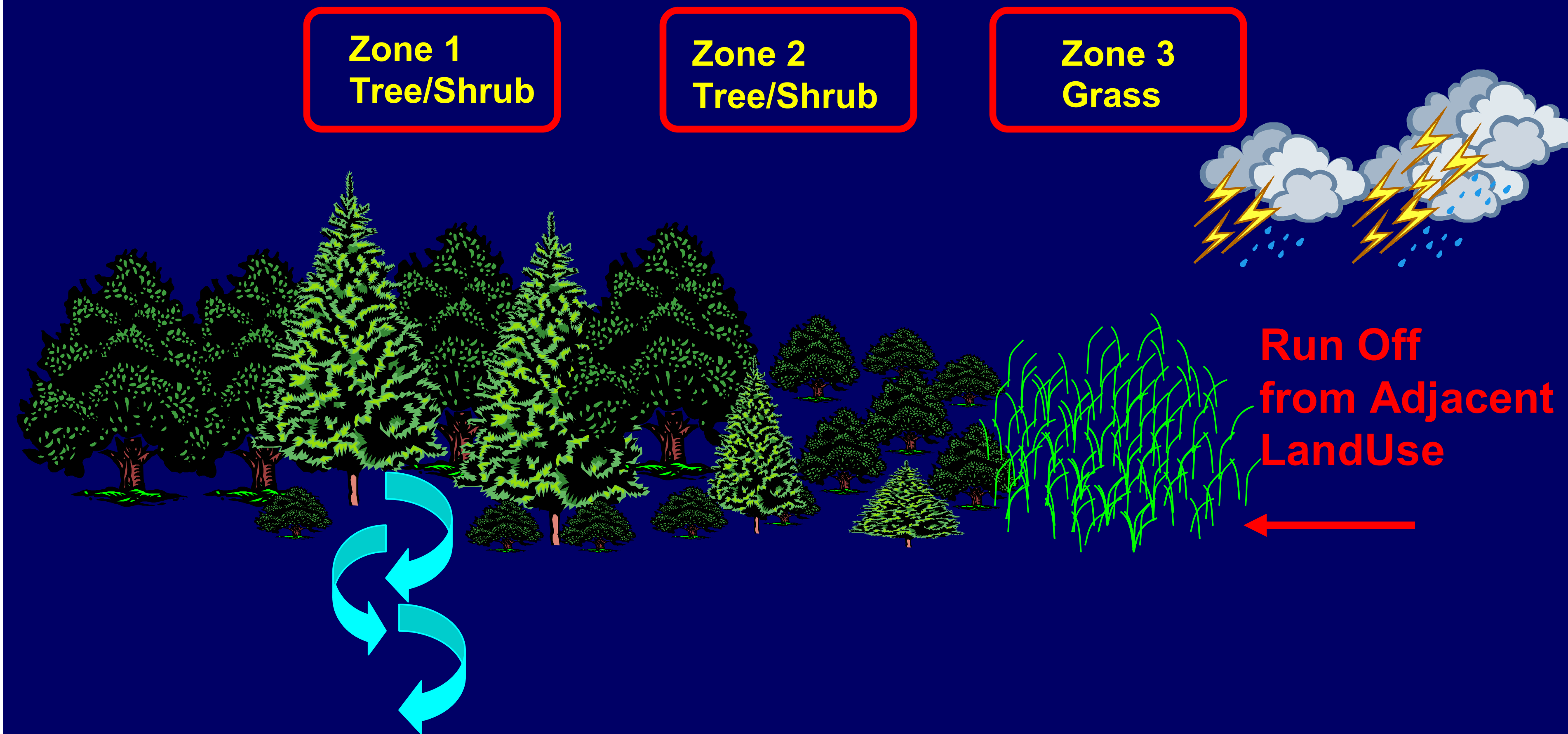
- Land existing adjacent to or near body of water that directly effects or is affected by the water

- Area managed to reduce impacts of an adjacent land use

Chesapeake Bay Watershed



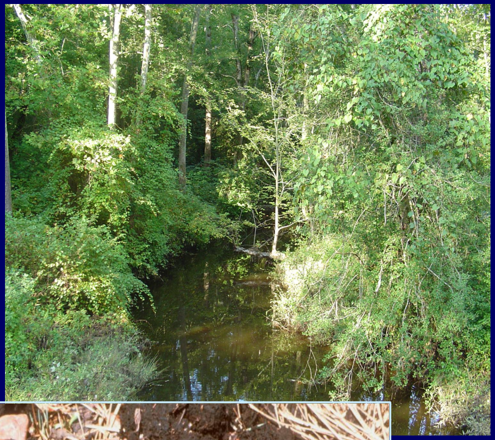
Three Zone Streamside Riparian Buffer

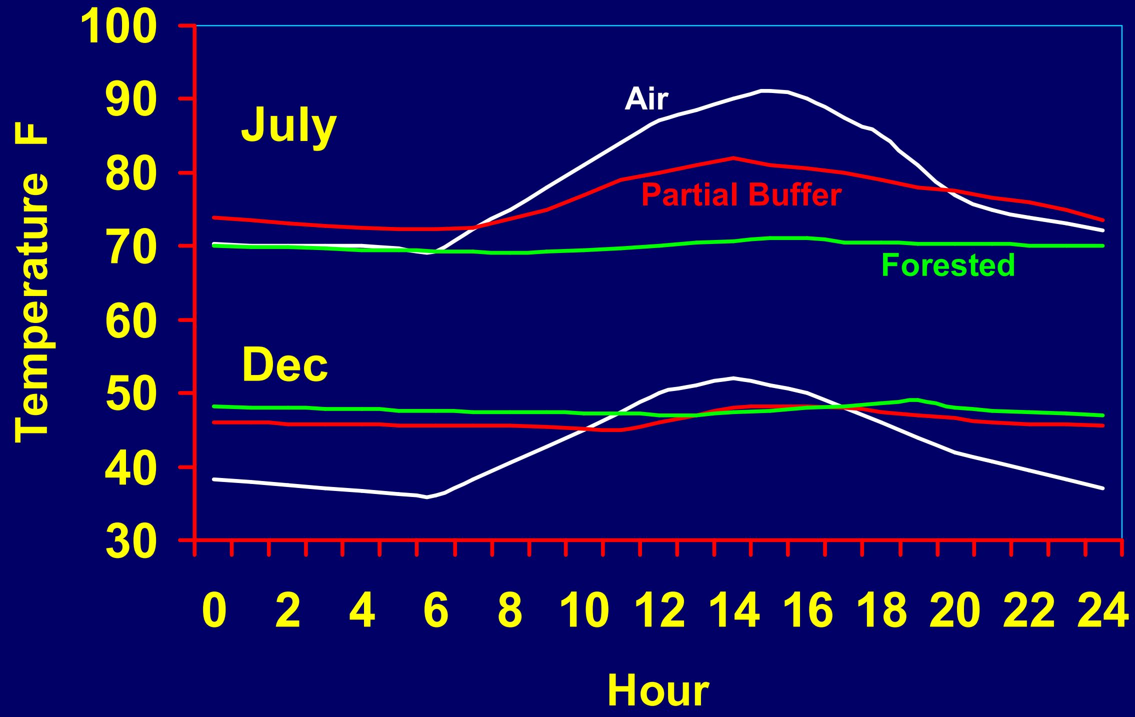


Riparian Vegetation Buffer Processes that Reduce Contaminant Loadings

- Shading
- Hydrologic Alteration
- Sedimentation
- Soil Formation
- Plant Uptake
- Denitrification

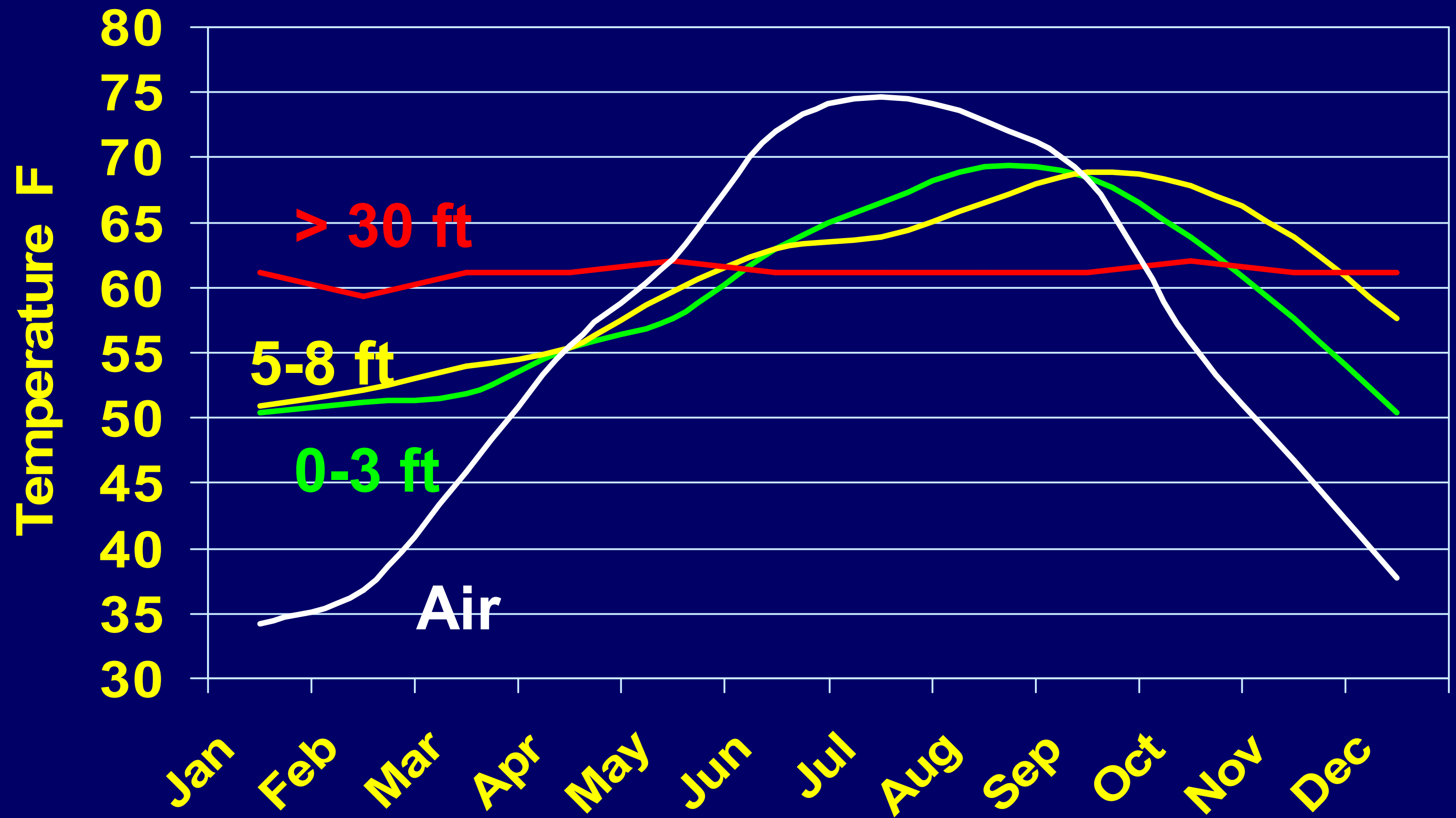
Diurnal Stream Temperature Variation





From Hewitt and Fortson 1982 (SE Georgia)

Mean Monthly Groundwater Temperatures



Annual Sediment Loss

lbs. per acre

Vegetative Buffer Erosion Control

- Rainfall interception
- ↑ Soil infiltration rates
- Promote diffuse flow
- Deep and high density roots prevent gulley or channel formation
- Tall/stiff stems provide year-round protection for downwind soils

Vegetative Buffer Zone Reductions of Sediment in Surface Runoff

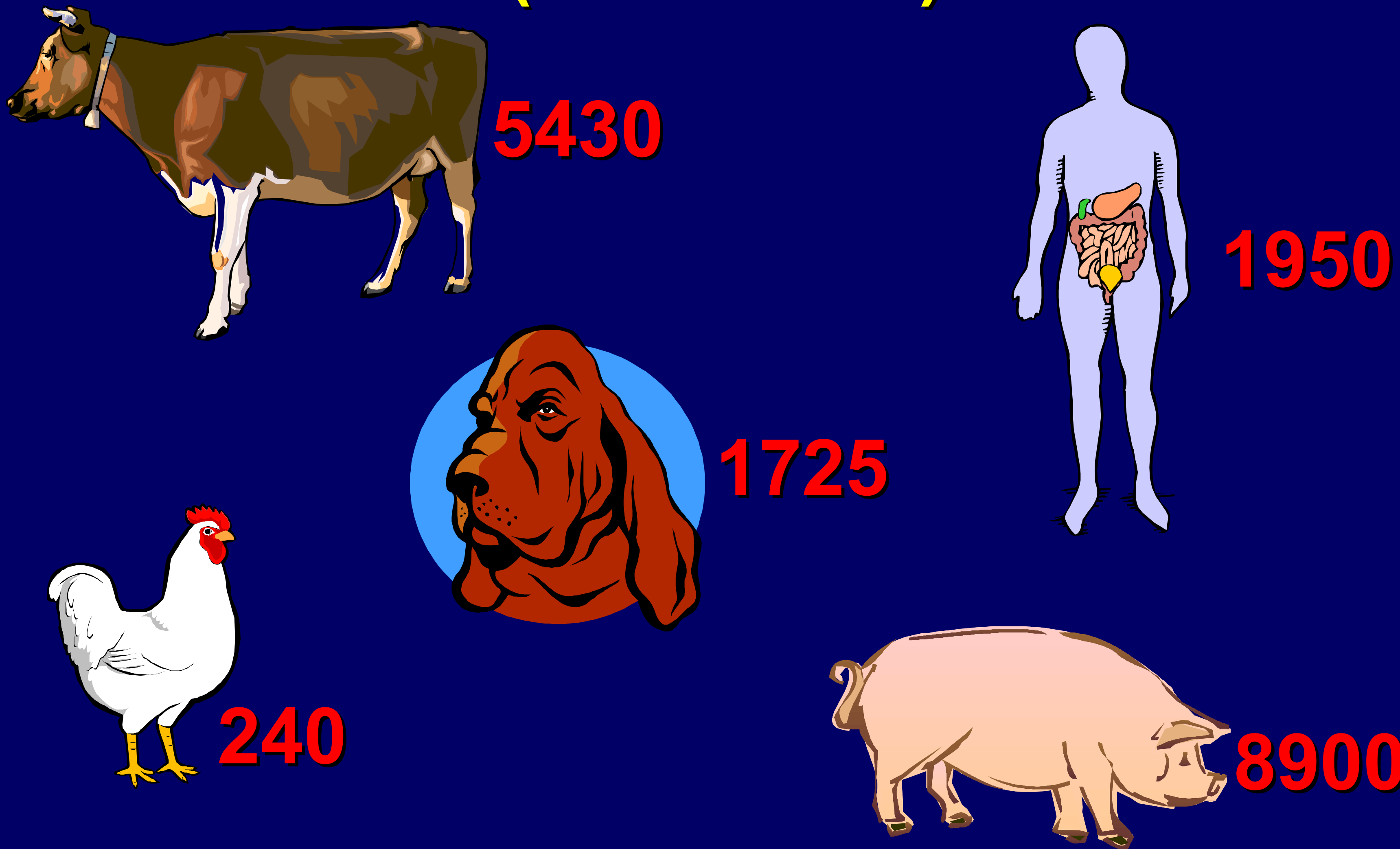
Buffer Type	Width m	% Sediment Reduction
Grass	4.6	61
Grass	9.2	75
Forest	19	90
Forest/Grass	19/4.6	96
Forest/Grass	19/9.2	97

Characteristics of "Typical" Residential Wastewater

Parameter	Mass Loading (gm/cap/day)	Concentration (mg/l)
Solids		
Total	115-170	680-1000
Volatile	65-85	380-500
Suspended	35-50	200-290
Oxygen Demand		
BOD_5	35-50	200-290
Chemical	115-125	680-730
Nutrients		
Total Nitrogen	6-17	35-1000
Ammonia	1-3	6-18
Nitrites/Nitrates	<1	<1
Total Phosphorus	3-5	18-29
Phosphate	1-4	6-24
Bacteria		
Total Coliforms*		$10^{10} – 10^{12}$
Fecal Coliforms*		10^{8} - 10^{10}

*organisms per L

Daily Discharge of Total Coliforms (in millions)



Bacteriological Water Quality of Surface Water Runoff

Surface Runoff Source	Total Coliforms (organisms/100ml)	Fecal Coliforms (organisms/100ml)
Grasslands		
Grazed pasture	6000-329,000	1000-57,000
Hayfield	4000-71,000	660-1,070
Croplands	15,800-50,000	5,400-14,300
Urban		
Business/Residential	58,000	10,900
Stormwater/ Sewage	20,000,000	4,245,000
Wooded	90,000	960

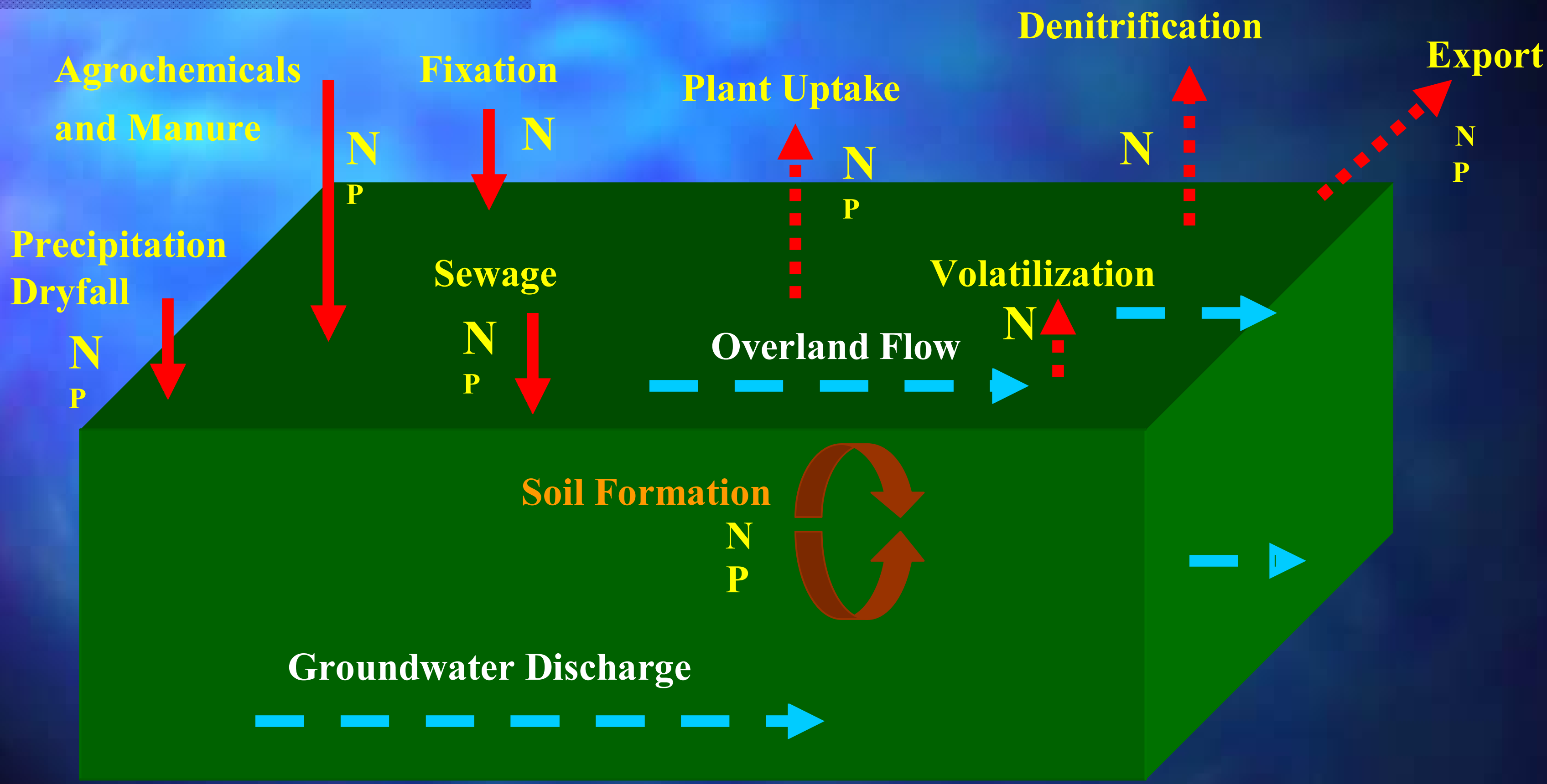
Anthropogenic Inputs of Nutrients

Domestic/Industrial Wastewater Discharges

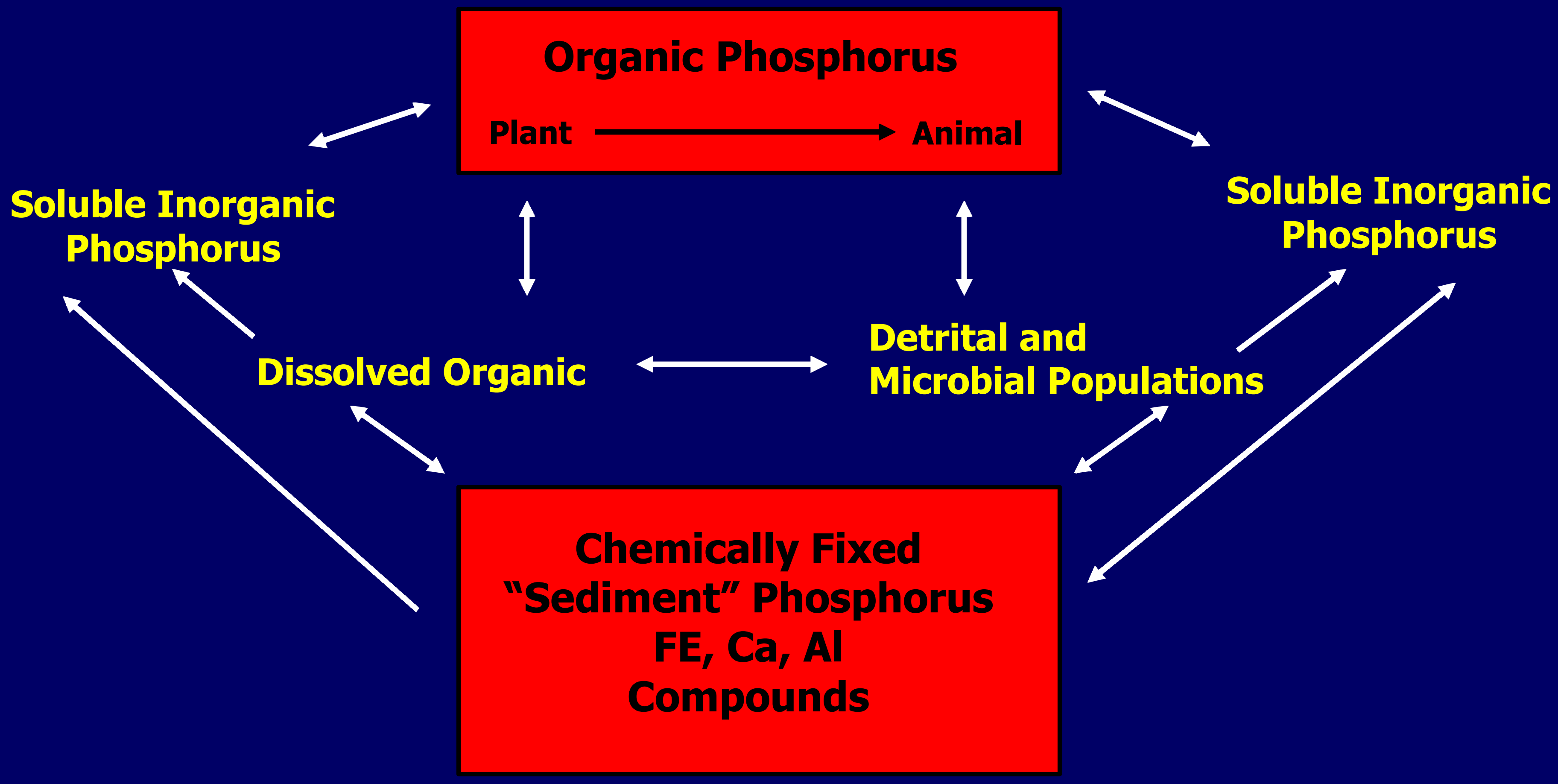
Automobile and Industrial Emissions

Agricultural Inputs

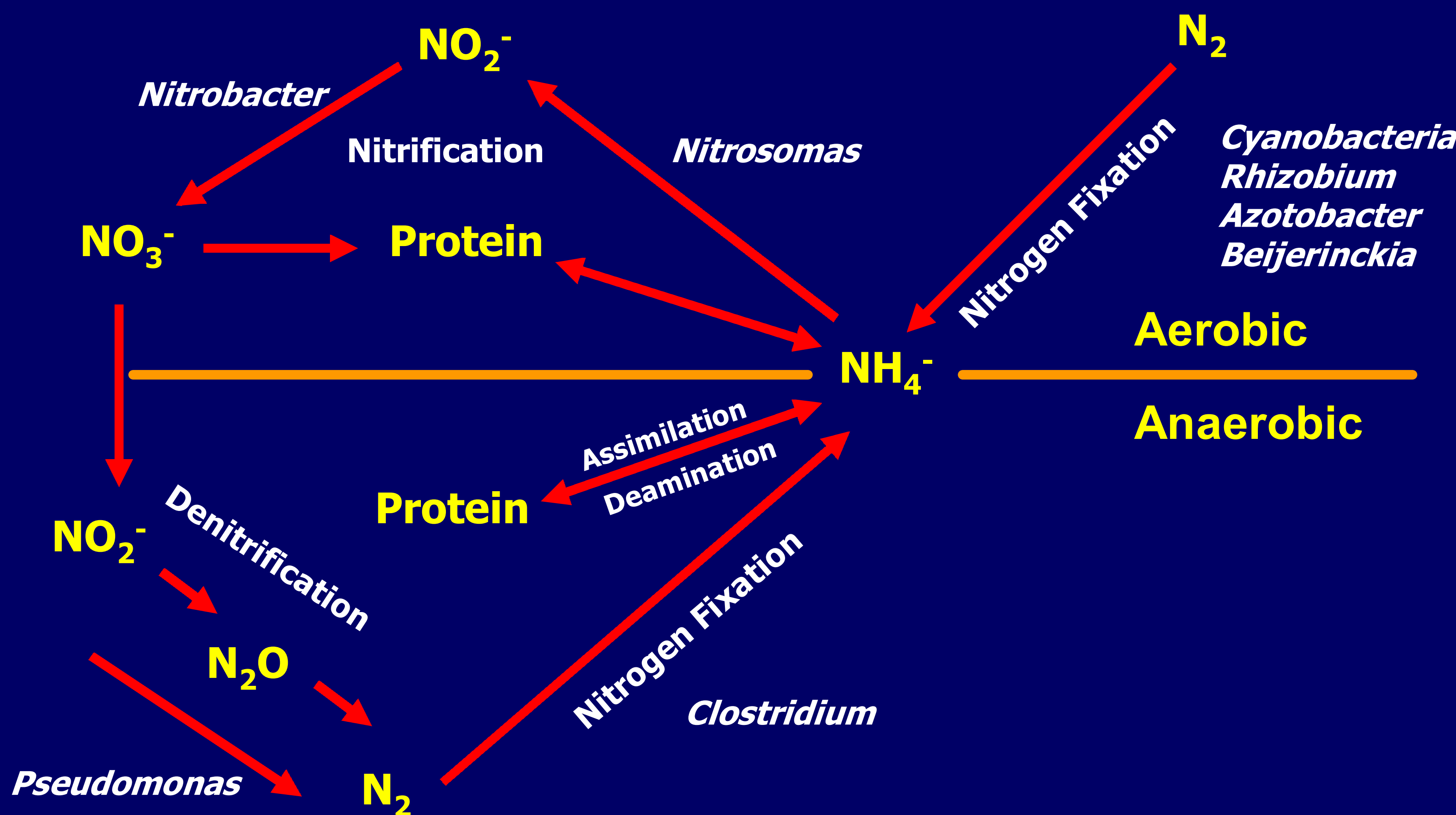
Nutrient Transport within a Watershed



Phosphorus Cycle



Nitrogen Cycle

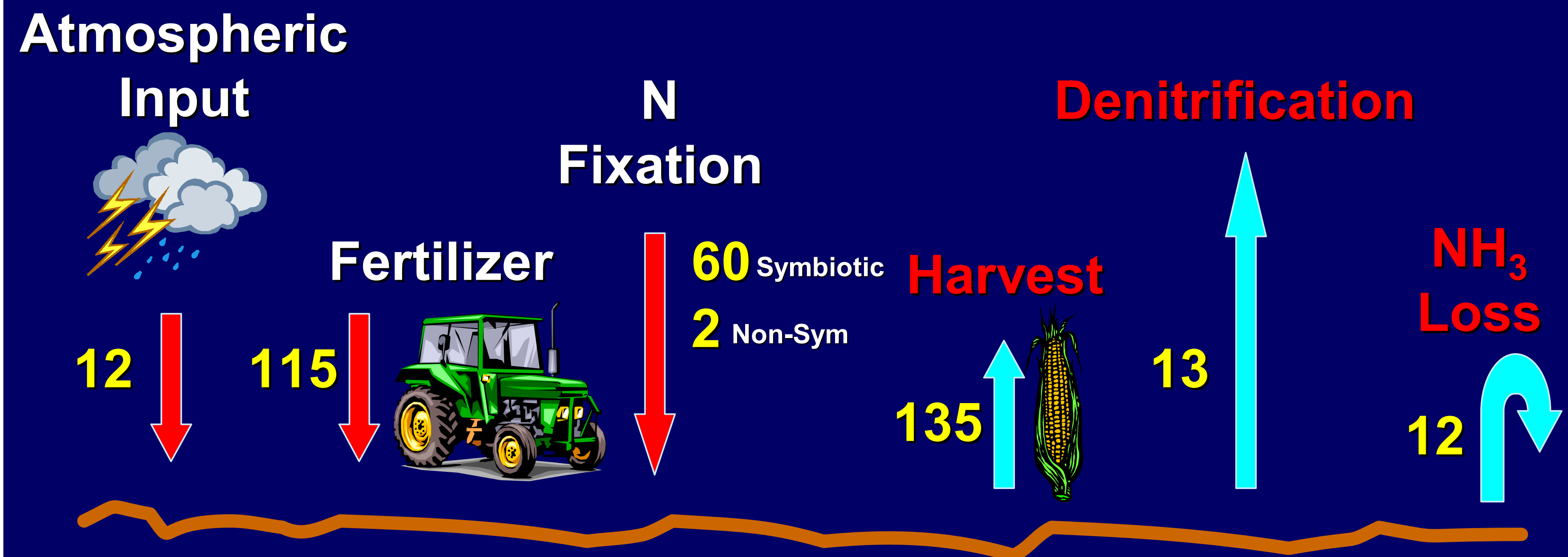


Annual Nutrient Loading Estimates

Land Use	Nitrogen	Phosphorus
Agricultural		
Row crop	110-135 lb/acre	22 lb/acre
Hay	80-110 lb/acre	18 lb/acre
Orchard	35-90 lb/acre	18-27 lb/acre
Residential		
Septic tank	12-33 lb/house	3-5 lb/house
Lawn fert.	40-175 lb/acre	9-18 lb/acre
Precipitation	5-10 lb/acre	0.2-0.5 lb/acre

Representative Agricultural Land Use N Budget

2 yr rotation: corn/wheat/soy
Fertilizer: 130/100/0 lbs/acre
Harvest: 120/55/35 bu/acre
N Content: .7/1.1/3.3 lbs/bu



(12+115+62) - (135+13+12) = 29 lbs / acre

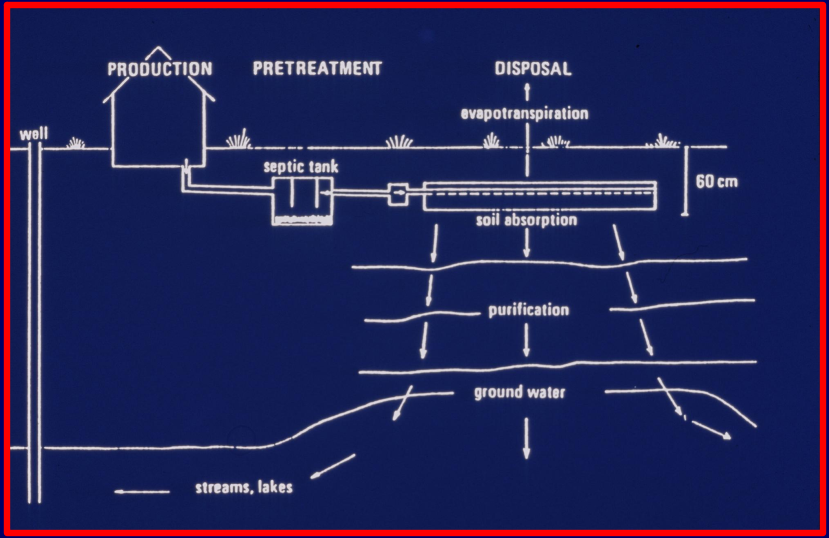
Inputs Outputs Residuals

EXPORT

Nitrogen Runoff Losses from Agricultural Fields: Groundwater versus Surface Runoff

Reference	Site Location	Subsurface N Loss kg/ha/yr	Surface Runoff N Loss kg/ha/yr
Peterjohn and Correll 1984	Rhode River, MD	23.1 TN (74%)	7.9
Staver and Brinsfield 1995	Queen Annes Co., MD	23.9 TN (91%)	2.1 – 2.4
Hubbard and Sheridan 1983	Coastal Plain, GA	23.1 NO_3^- (91%)	0.3
Lowrance 1992	Tifton, GA	29.1 TN (93%)	2.1

Contaminant Reductions within Septic Tank Systems



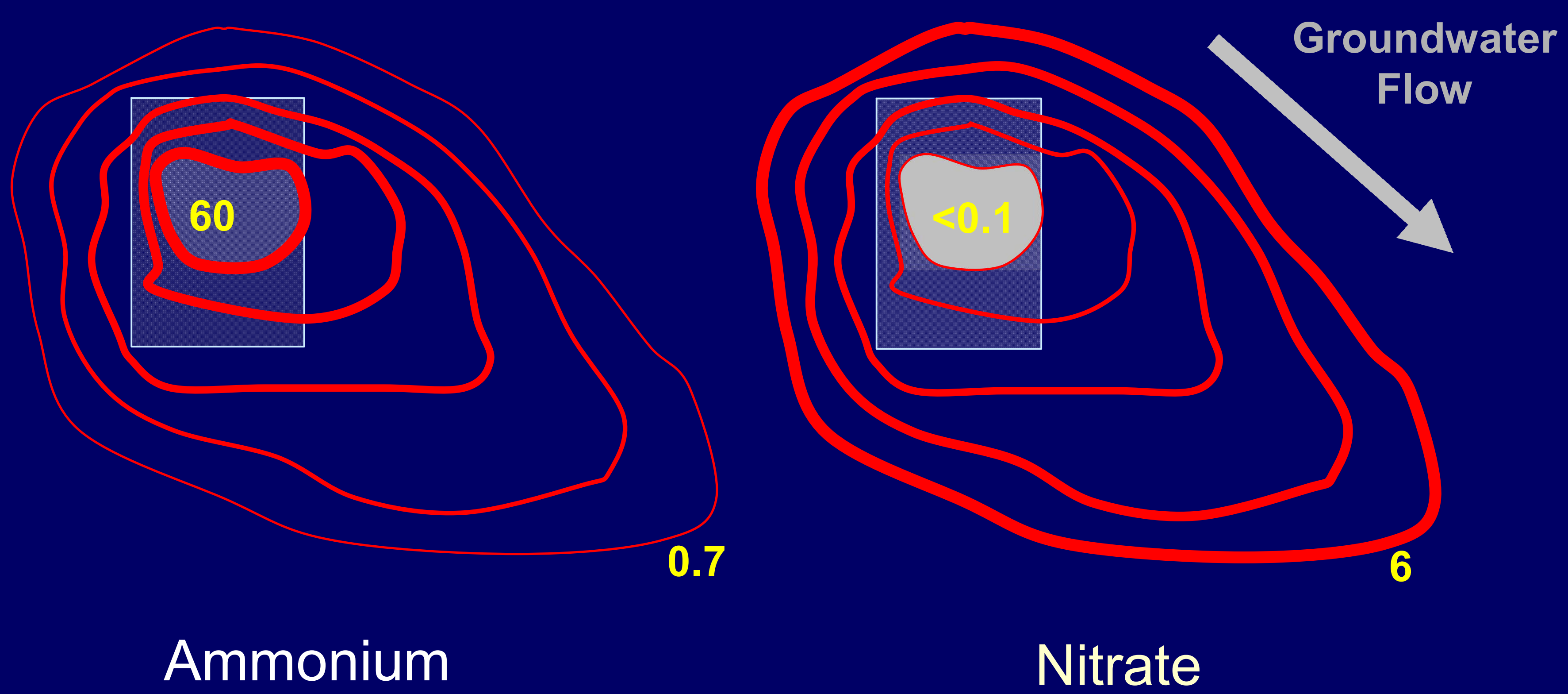
Septic Tank

- 35-45% ⬇ in TSS
- 15% ⬇ in BOD
- 10% ⬇ in Phosphorus
- 10% ⬇ in Nitrogen
- Limited ⬇ in Fecal Coliform

Soil Absorption System

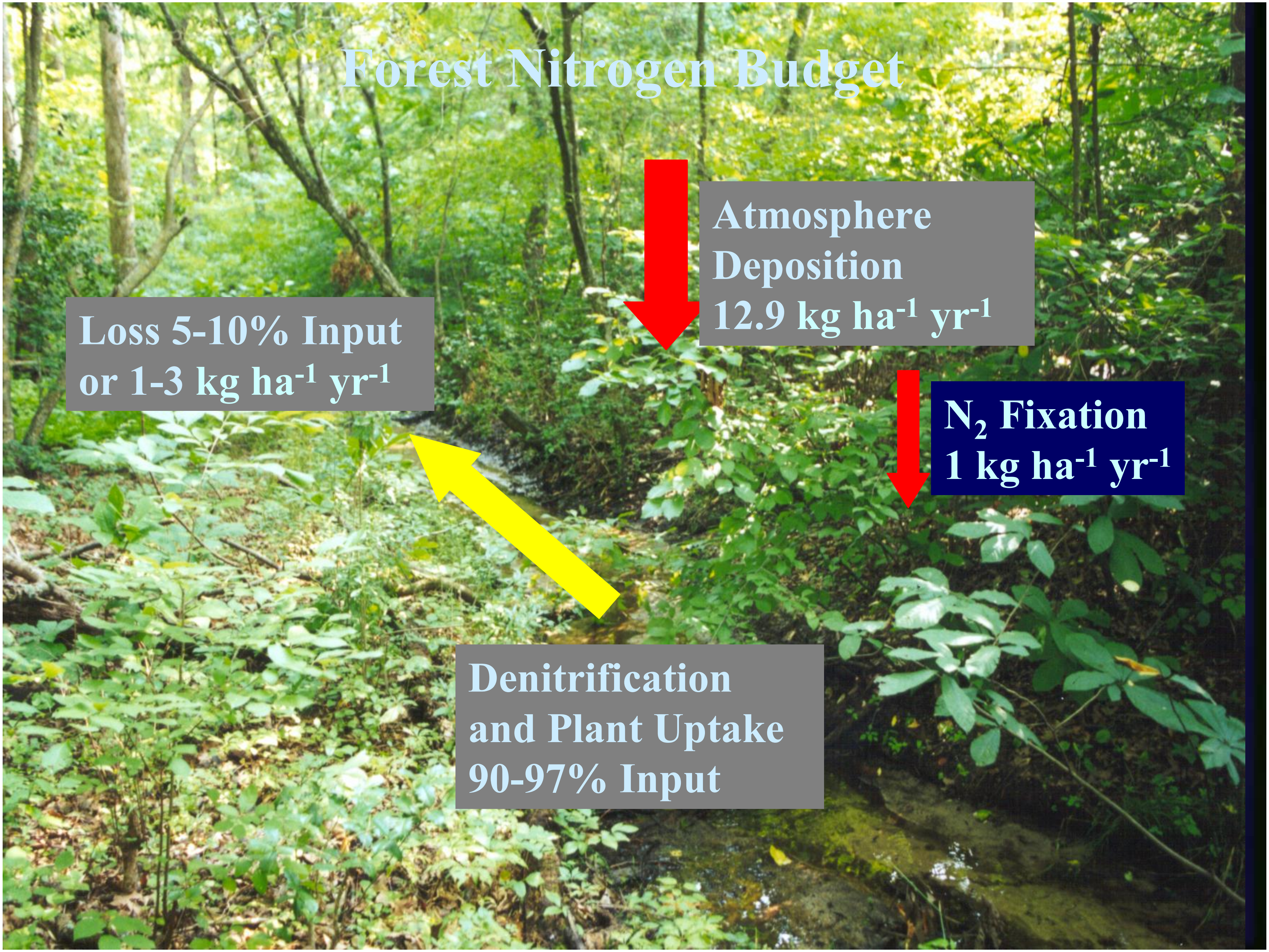
- 75-90% ⬇ in TSS, BOD, COD
- 25-50% ⬇ in Phosphorus
- 5-25% ⬇ in Nitrogen
- Near 100% in Fecal Coliform

Nitrogen Concentrations (ppm) Surrounding a Septic Tank Drainfield



Annual Ground Water Nitrogen Loadings for Residential Housing Using Septic Tanks

Reference	Location	kg Household	kg person
Koppelman 1978	Long Island, NY	6.9 (TDN)	2.3 (TDN)
Gold et al. 1990	Kingston, RI	9.5 (DIN)	3.2 (DIN)
Weiskel and Howes 1991	Buzzards Bay, MA	4.2-7.3 (TDN)	1.6-2.7) (TDN)
Maizel et al. 1997	Chesapeake Bay	6.8-10.0 (TDN)	2.4-3.5 (TDN)
Valiela et al. 1997	Waquoit Bay, MA	5.2 (TDN)	2.9 (TDN)
Reay 2003	Coastal Plain, VA	5.7-10.7 (DIN)	2.4-2.9 (DIN)



Forest Nitrogen Budget
Atmosphere Deposition 12.9 kg ha-1 yr-1
Loss 5-10% Input or 1-3 kg ha-1 yr-1
N2 Fixation 1 kg ha-1 yr-1
Denitrification and Plant Uptake 90-97% Input

Groundwater-Surface Water Nitrogen Loading Reduction Strategies

- **OSWDS's**
  - Advanced treatment of OSWDS effluent
  - Low pressure systems

- **Agricultural Lands**
  - Plant/soil N analysis
  - Timing, method, and type of fertilizer
  - Liming
  - Irrigation management
  - Cover crops

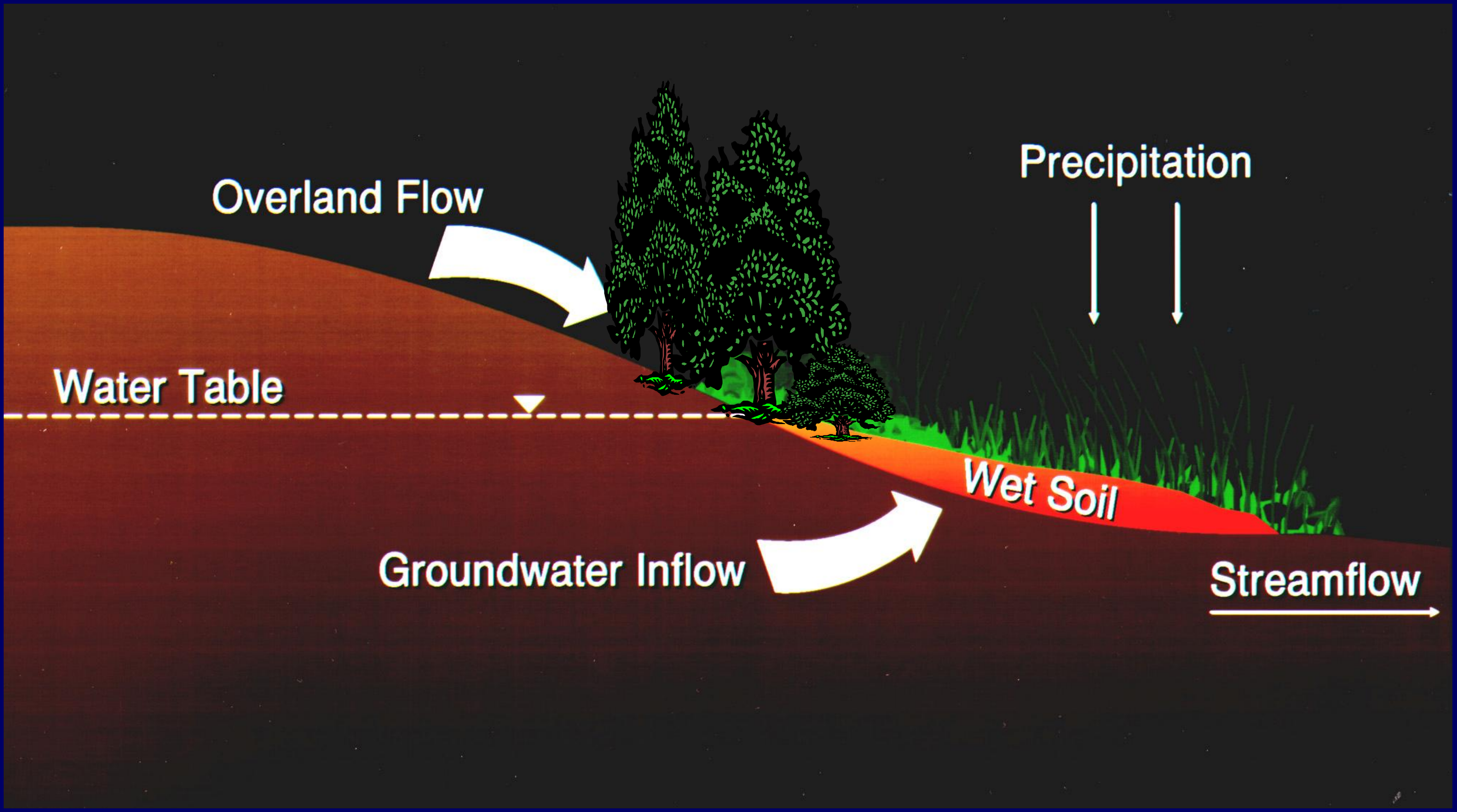
- **Riparian Buffers and Intertidal Ecosystems**
  - Upland vegetative riparian buffers
  - Fringing wetlands
  - Low Eh nearshore sediments

Riparian Vegetation Buffer Processes that Reduce Nutrient Loadings

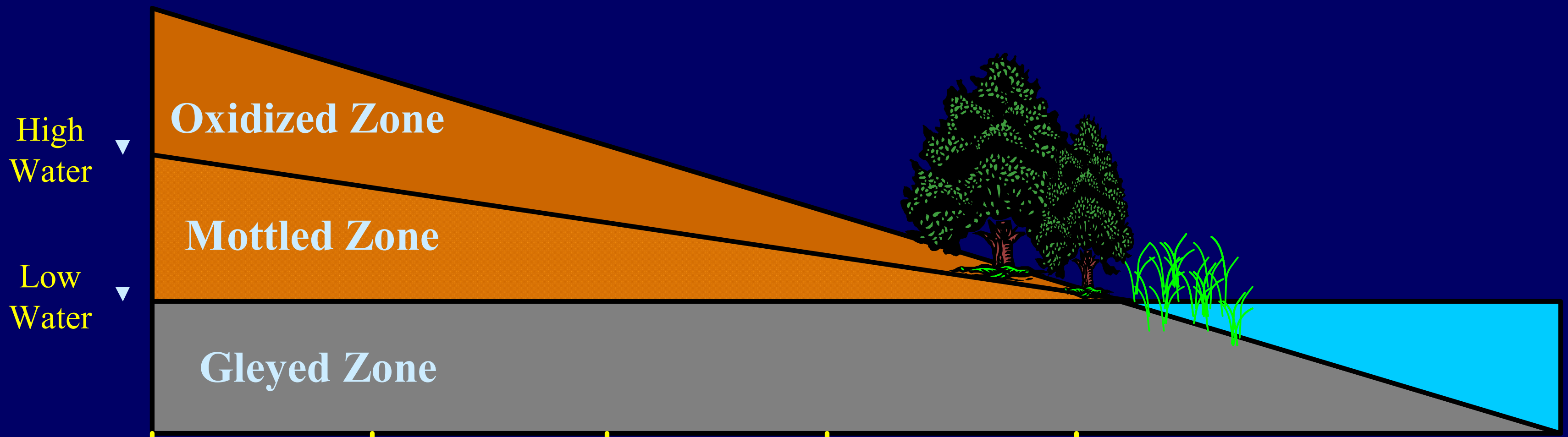
- Sedimentation
- Soil Formation
- Plant Uptake
- Denitrification

Riparian Buffers in Landscapes

On slopes:



Soil Drainage along an Elevational Gradient



Well	Mod. Well	Som. Poor	Poorly	Very Poorly
Dk. Black	Dk. Black	Dk. Black	Black	Organic
Brown	Brown	Olv. Brown	Mottled	Black
Yel. Brown	Yel. Brown	Mottled	Gray	Gray
Olv. Brown	Mottled	Gray		
Mottled	Gray			

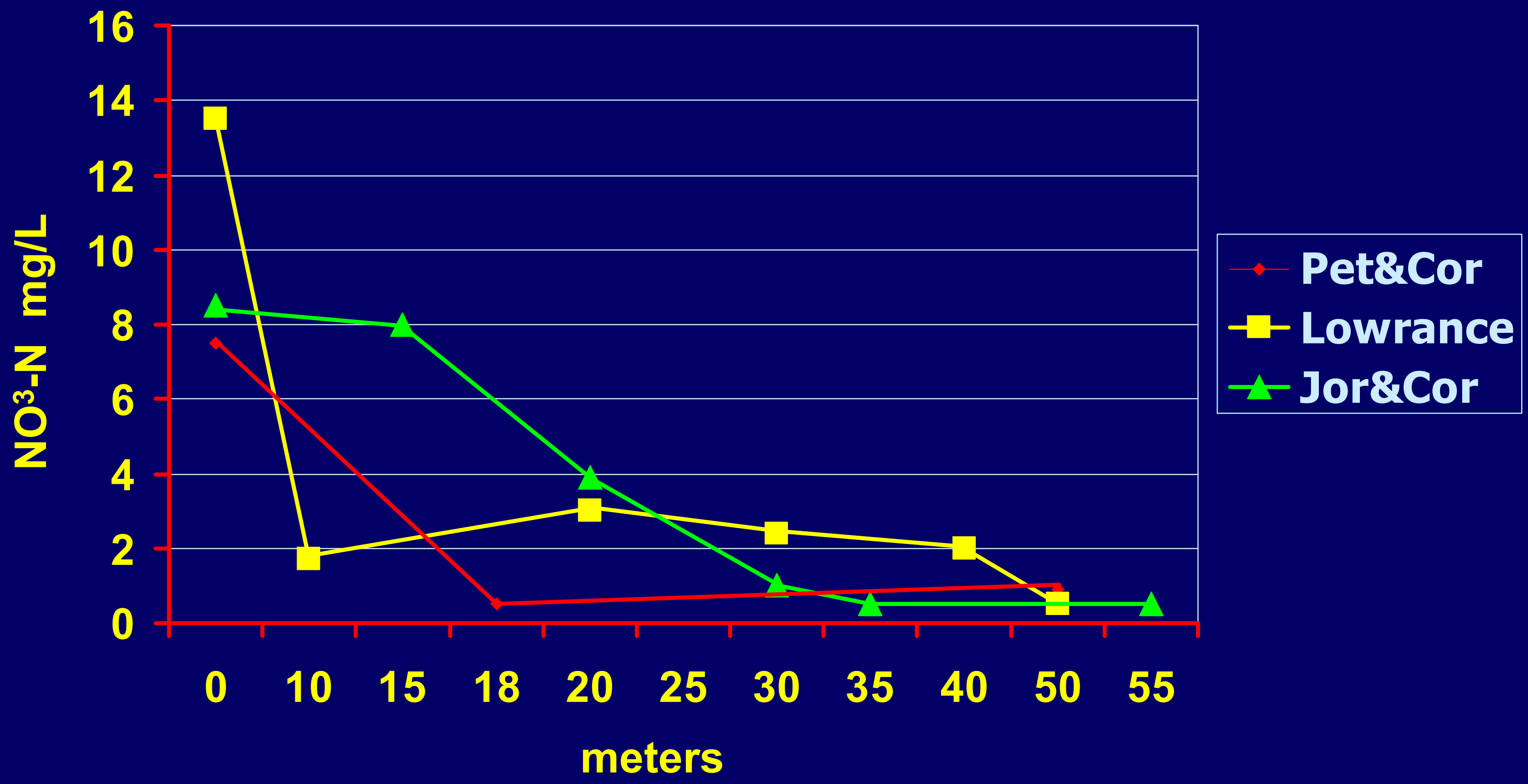
Vegetative Buffer Zone Reductions of Nutrients in Surface Runoff

Buffer Type	Width m	% N Reduction	% P Reduction
Grass	4.6	4	29
Grass	9.2	23	24
Forest	19	74	70
Forest/Grass	19/4.6	75	79
Forest/Grass	19/9.2	80	77

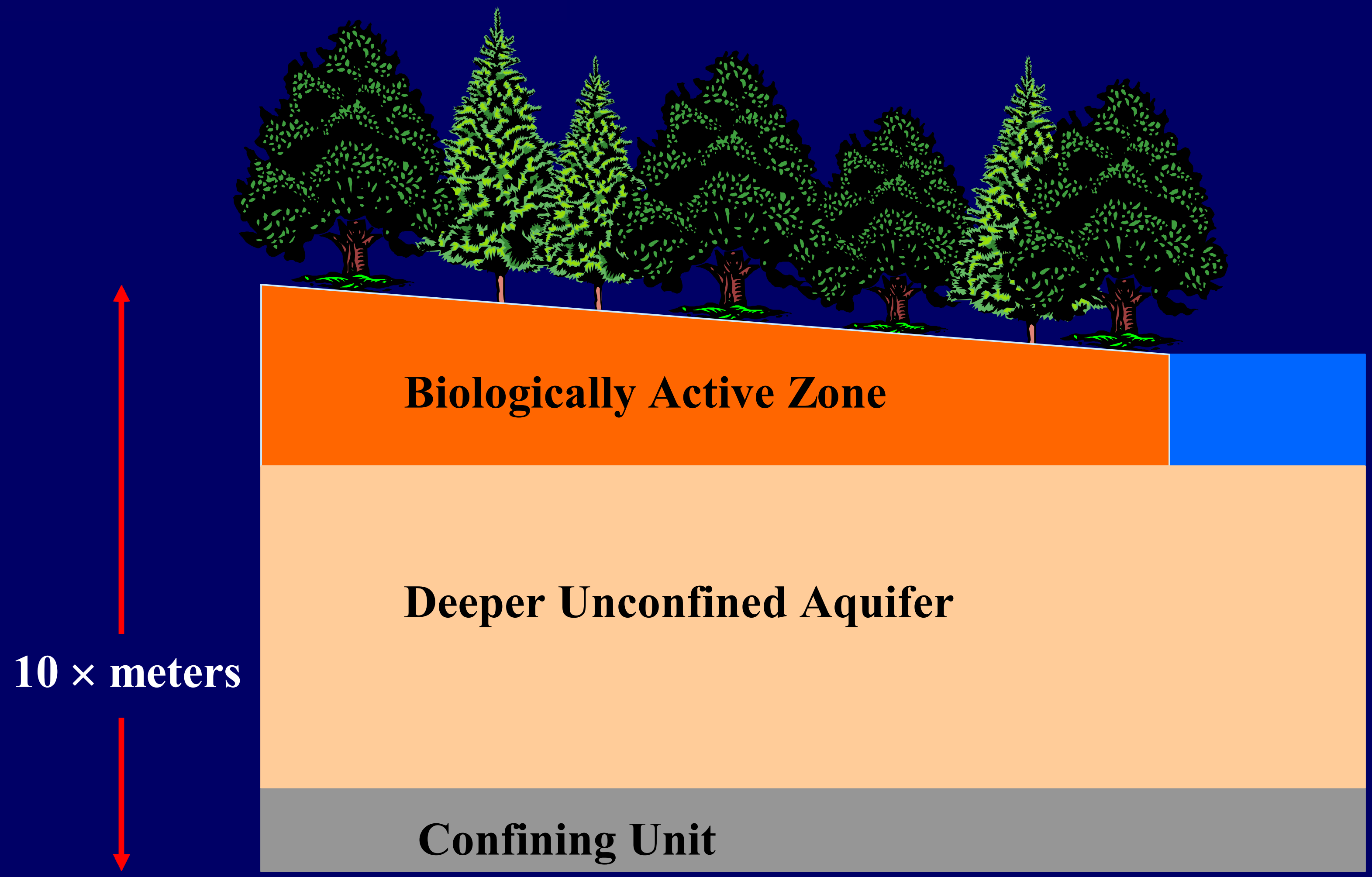
Inner Coastal Plain Setting

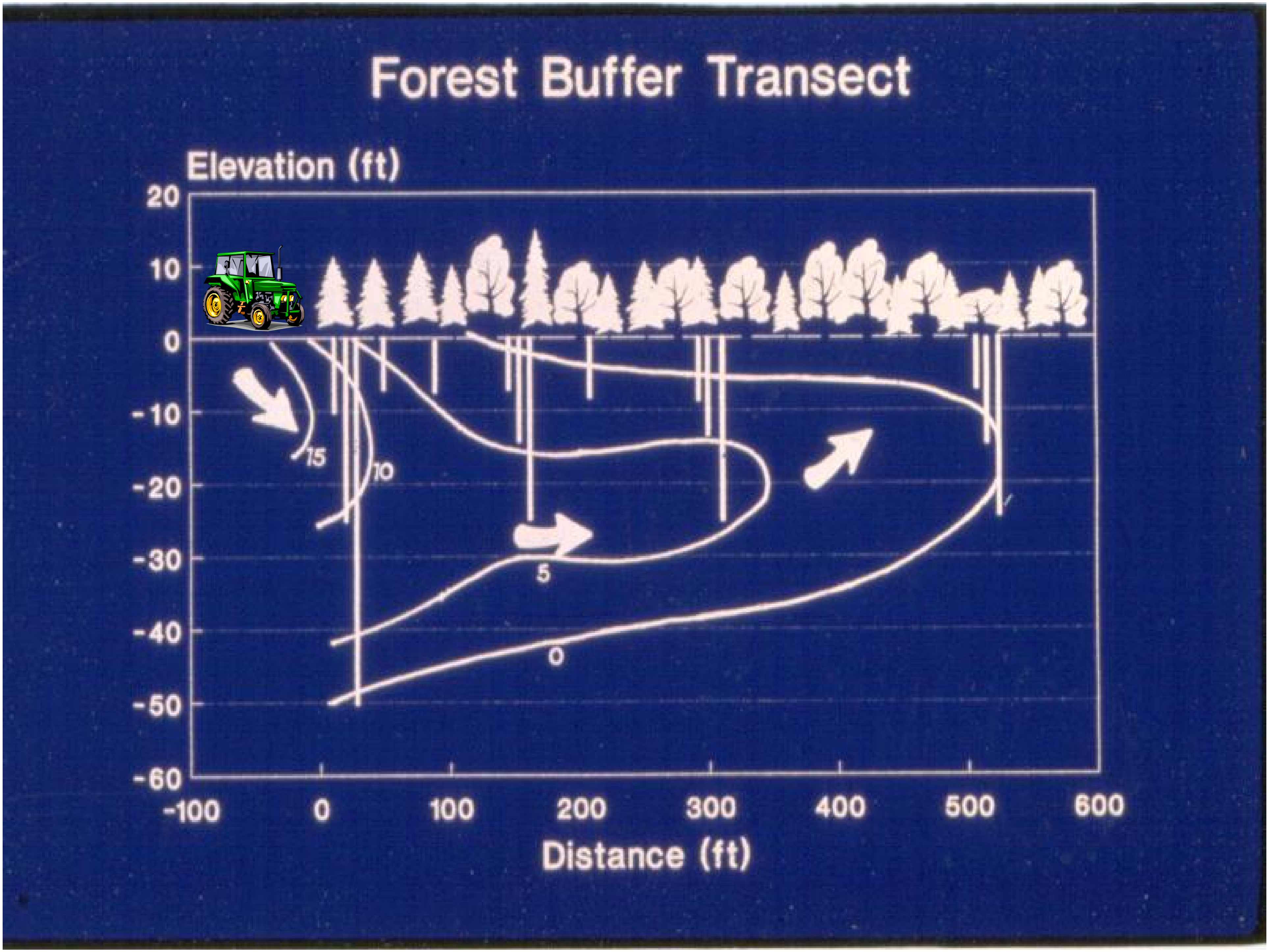
- Western shore and upper Eastern Shore
- High degree of stream incision
- Short flow paths
- High topographic relief
- Finer textured sediments/soils
- Well drained uplands and poorly drained riparian regions

Groundwater Nitrate Levels Beneath Riparian Forests



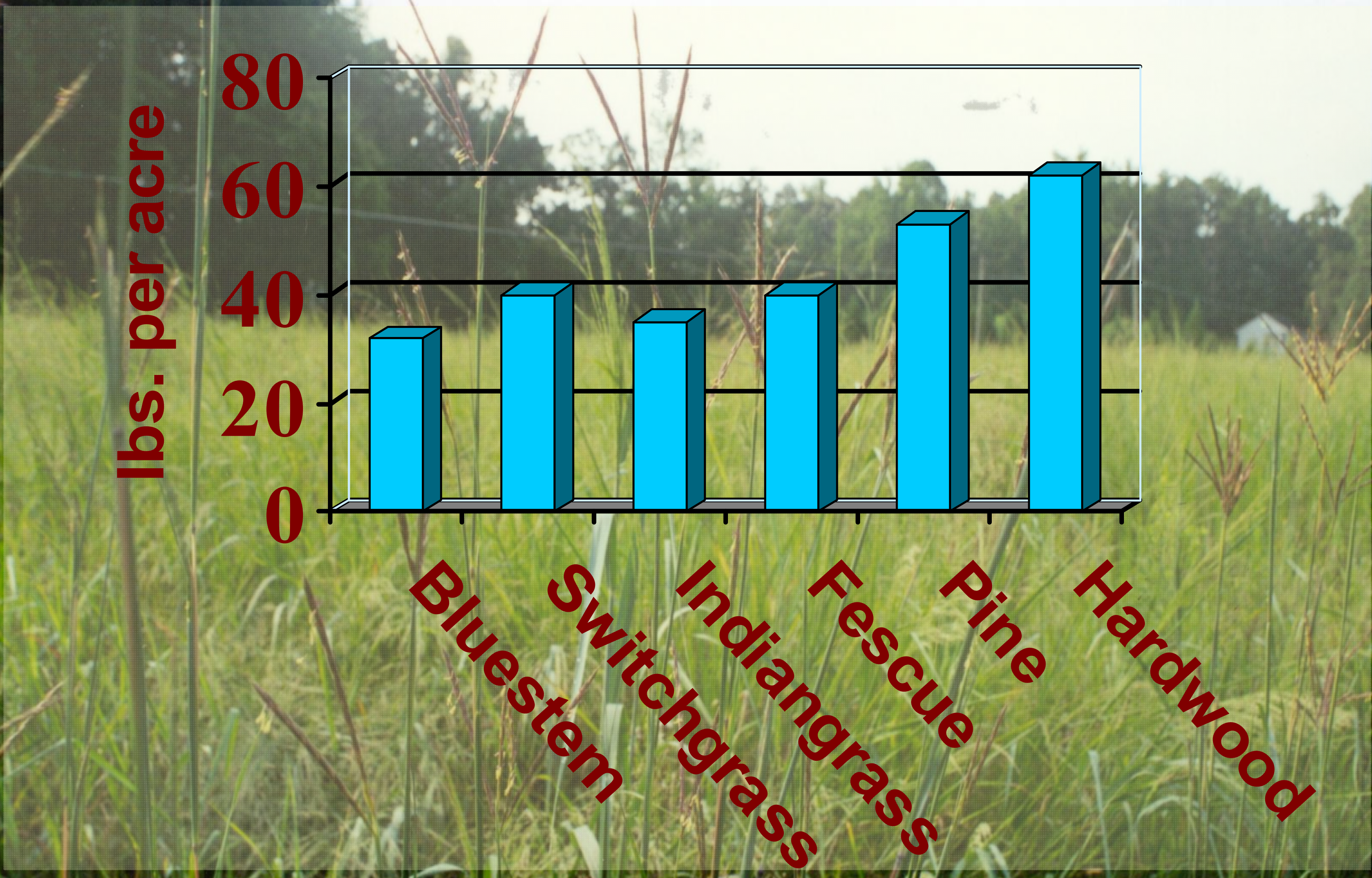
Outer Coastal Plain Setting



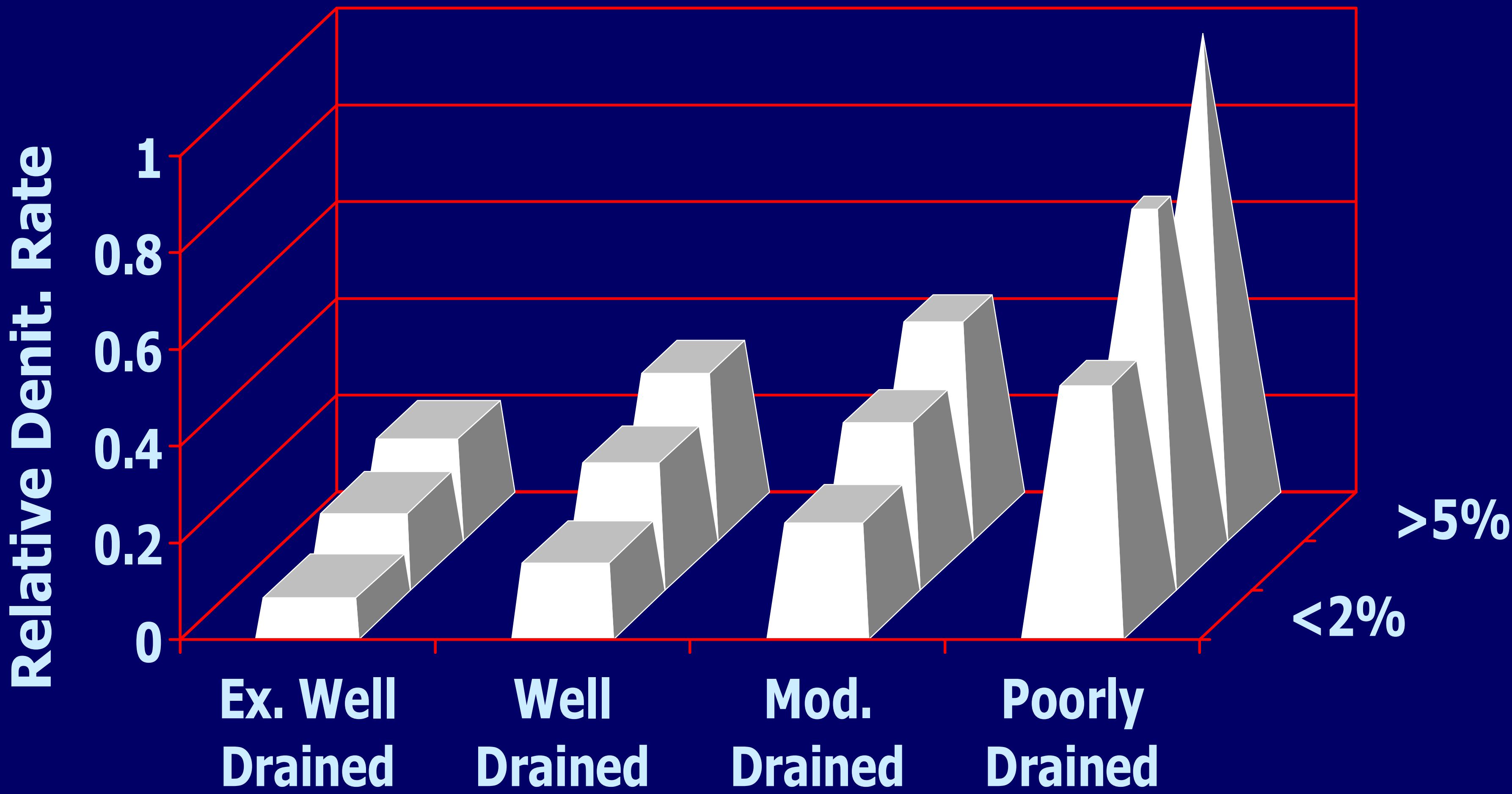


Forest Buffer Transect
Elevation (ft)
20
10
0
-10
-20
-30
-40
-50
-60
15
10
5
0
-100
0
100
200
300
400
500
600
Distance (ft)

Plant Nitrogen Uptake



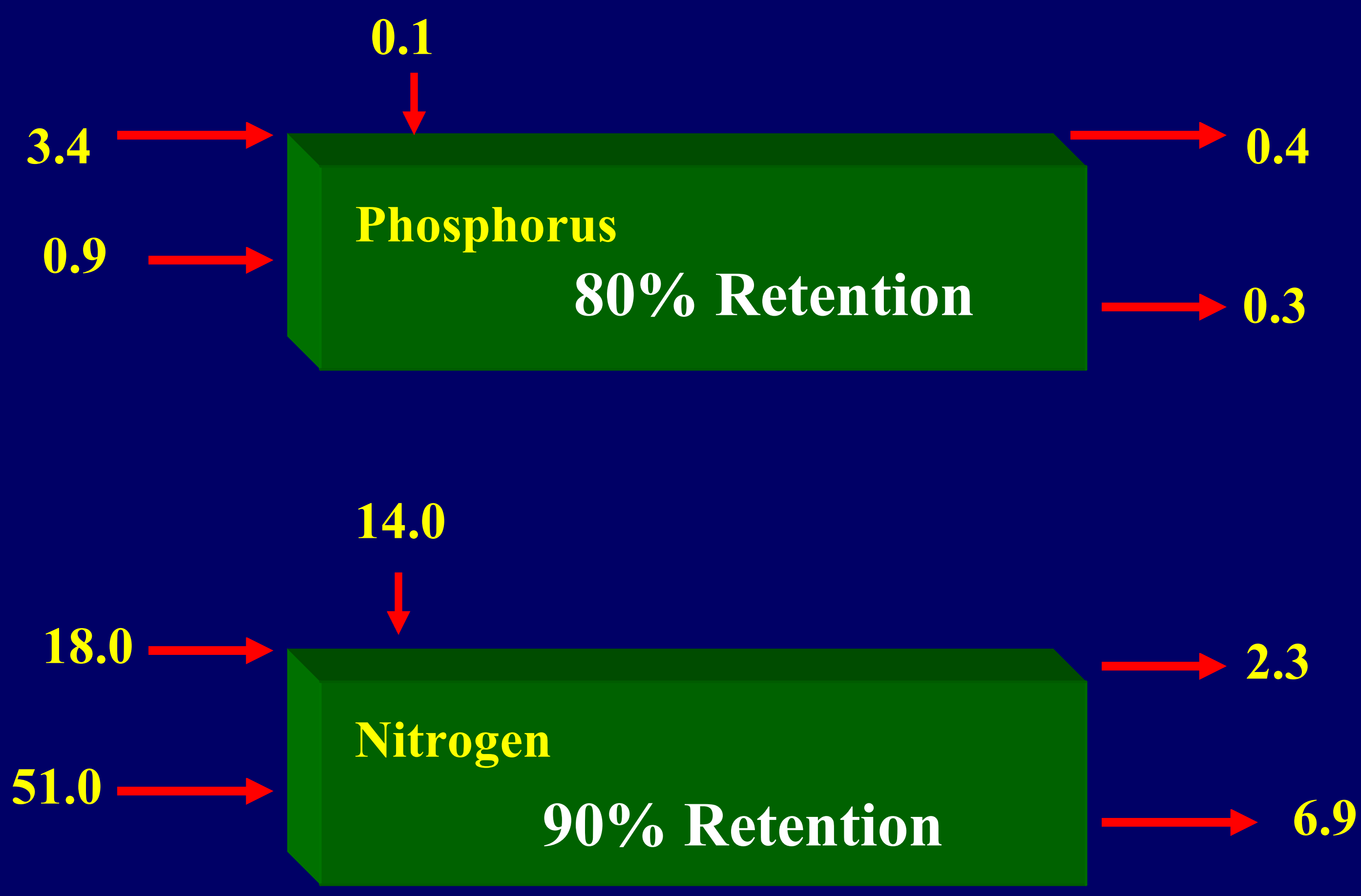
Denitrification Rates
Influence of Drainage Classification and Soil OM



Representative Denitrification Rates

Environment	In Situ Rates lbs/acre yr	Amended Rates lbs/acre yr
Salt Marsh	13	6150
Stream Bed	0.2 - 0.3	3-7
Top Soil	0.7 – 25	14075
Riparian Wetland		
poorly drained	0.1 - 74	12685
well drained	0.5 - 23	133
Grasslands		
poorly drained	15 – 100	5260
well drained	0.5 – 53	2970

Annual Riparian Forest Nutrient Budget



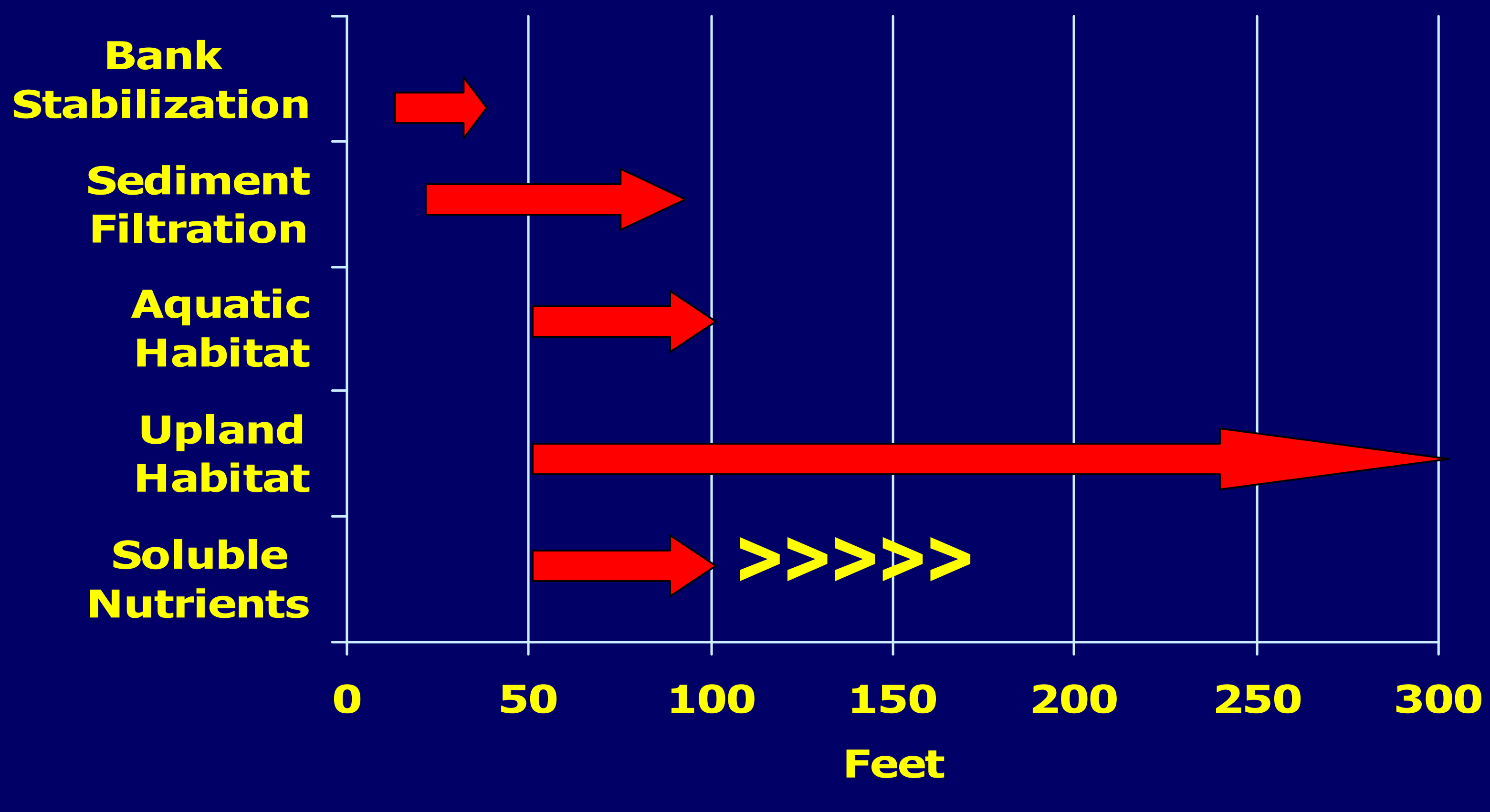
Units expressed as kg/ha

Riparian Forests
Cost Effective and a Natural Value

	Kg N ha^{-1} yr-1	Dollar Value
Denitrification	30-40	\$33 - \$762
Woody Storage	12-50	\$13 - \$952
	Total	\$46 - \$1714
Nitrogen Budget	26-74	\$29 - \$1410

Based on annual wastewater treatment plant costs:
\$0.50-\$8.65 per lb.

Estimated Buffer Width versus Specific Benefit



Open Season on Riparian and Intertidal Vegetative Buffers?

Success in enhancing riparian vegetative buffers will depend as much on cultivating a stewardship ethic among landowners and "stakeholders" as it will on planting trees, shrubs and grasses